The Planetary Computer for Studying the Planet Earth

Information Science and Technology Colloquium
NASA Goddard Space Flight Center

May 21, 2003

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Director, California Institute for Telecommunications and Information Technologies

Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

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Abstract

After 15 years of building out the wired Internet infrastructure around the world, new extensions of this core infrastructure are rapidly emerging. Wireless Internet access from both unlicensed and licensed radio bands are spreading quickly, dedicated dark fiber optical networks are being set up between universities in many states and countries, the NSF, NIH, NASA, and foreign science agencies are starting a decade long construction of a new generation of shared scientific facilities to accelerate data intensive science, federated data systems are being interlinked, computing is decentralizing into a Grid framework, and high resolution and virtual reality interfaces are becoming more common. These trends will result in a vastly more powerful global knowledge and collaboration system than exists today. I will give examples of how the new California Institute for Telecommunications and Information Technology (www.calit2.net) is creating "Living Laboratories" for the earth sciences with its partner, the UCSD Scripps Institution of Oceanography, to explore these futures with interdisciplinary teams. The OptIPuter project, NSF's largest computer science award from last year and the Santa Margarita Ecological Reserve sensornets will be used as specific examples, along with the NSF EarthScope and GEON knowledge grids for the earth sciences.

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The Next S-Curves of Internet Growth: A Mobile Internet Powered by a Planetary Grid

- **Wireless Access--Anywhere, Anytime**
  - Broadband Speeds
  - "Always Best Connected"
- **Billions of New Wireless Internet End Points**
  - Information Appliances
  - Sensors and Actuators
  - Embedded Processors
- **Emergence of a Distributed Planetary Computer**
  - Parallel Lightwaves in Optical Backbone
  - Storage of Data Everywhere
  - Scalable Distributed Computing Power

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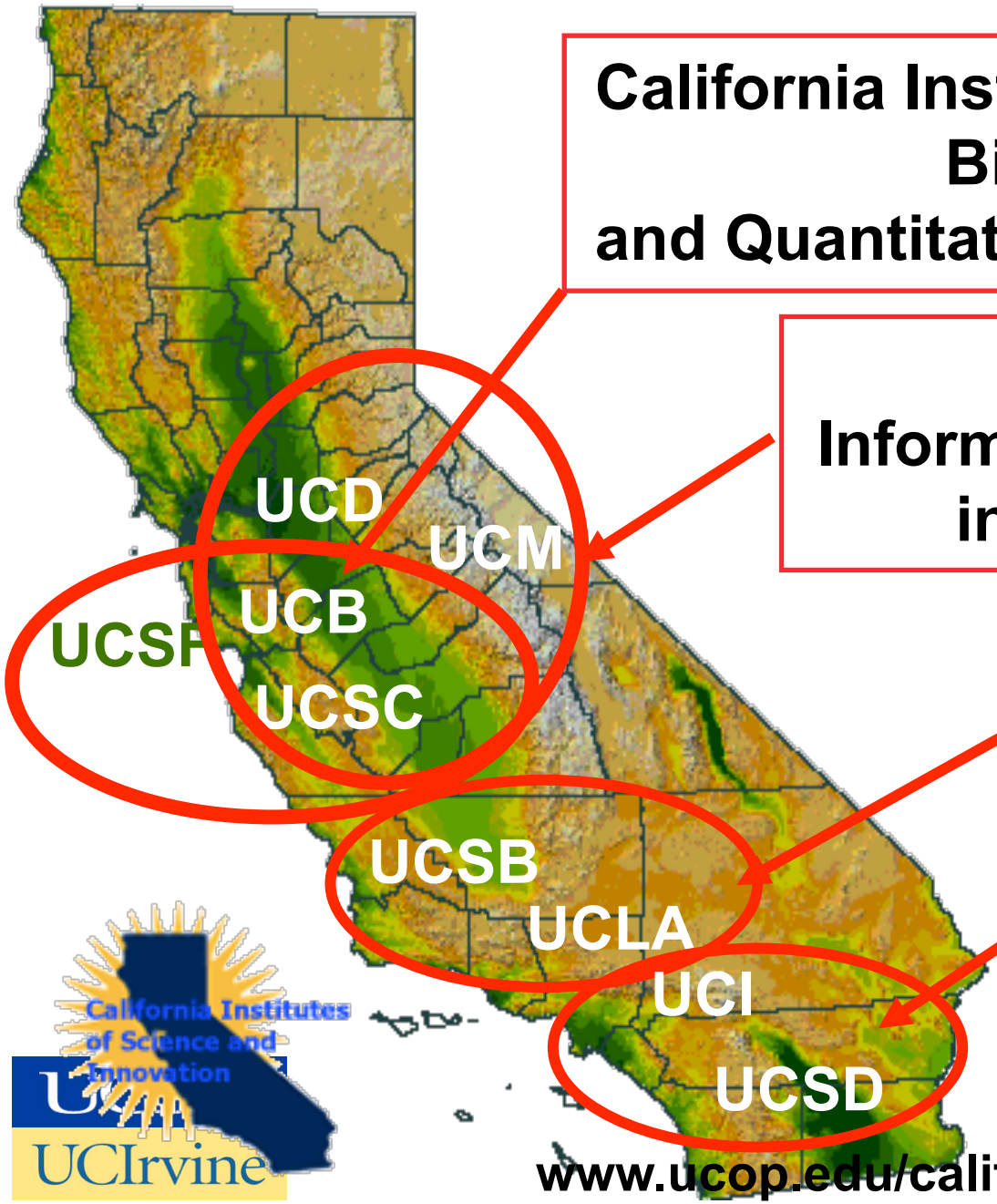
California's Institutes for Science and Innovation: A Bold Experiment in Collaborative Research



California Institute for Bioengineering, Biotechnology, and Quantitative Biomedical Research

Center for Information Technology Research in the Interest of Society

California NanoSystems Institute

California Institute for Telecommunications and Information Technology

California Institutes of Science and Innovation

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www.ucop.edu/california-institutes

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Cal-(IT)^2--An Integrated Approach the Future of the Internet

220 UC San Diego & UC Irvine Faculty Working in Multidisciplinary Teams With Students, Industry, and the Community

The State's $100 M

Creates Unique Buildings, Equipment, and Laboratories

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www.calit2.net

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The EOSDIS is the Largest e-Science Distributed Information Infrastructure

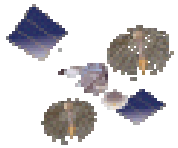
Data Acquisition

Flight Operations, Data Capture, Initial Processing, Backup Archive

Data Transport to DAACs

Science Data Processing, Info Mgmt, Data Archive, & Distribution

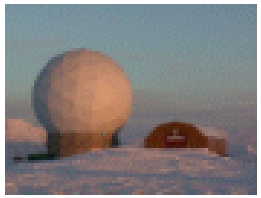
Distribution, Access, Interoperability, Reuse

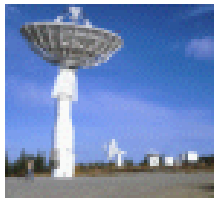


EOS Spacecraft

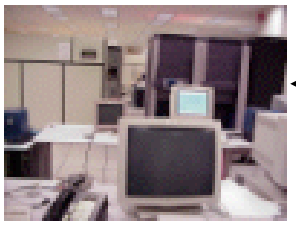
Tracking & Data Relay Satellite (TDRS)

White Sands Complex (WSC)

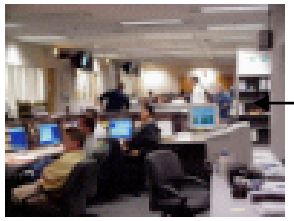




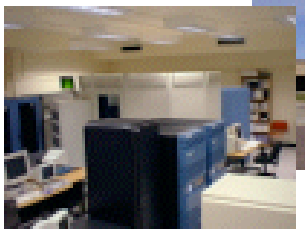
EOS Polar Ground Stations



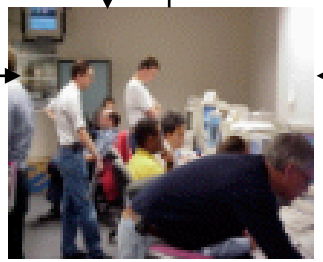
Data Processing & Mission Control



NASA Integrated Services Network (NISN) Mission Services



Distributed Active Archive Centers



Instrument Teams

NASA Internet

Research Users

Education Users

Value-Added Providers

Int'l Partners & DataCenters

Interagency Data Centers

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Distributed Cyberinfrastructure Will Underpin Many e-Science Community Resources

NEPTUNE
A Fiber-Optic Telescope to Inner Space

GENOMES to LIFE
BIOLOGICAL SOLUTIONS FOR ENERGY CHALLENGES
U.S. DEPARTMENT OF ENERGY

ALMA

ESDIS

GriPhyN
Data Intensive Science

NEES

LHC

BIRN

NEON
National Ecological Observatory Network

Sloan Digital Sky Survey

GEON

LIGO

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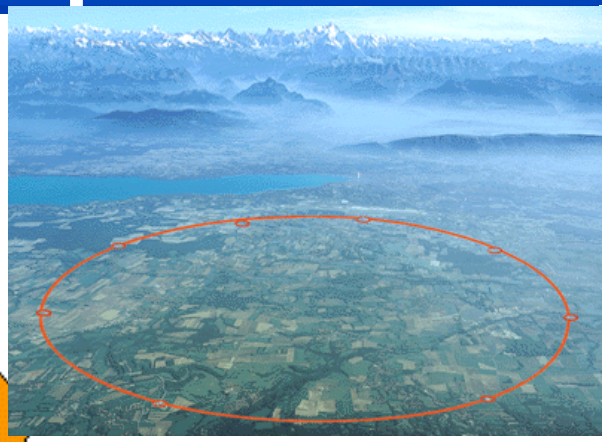
Distributed Data Grid Supporting International Particle Physics Experiments



Experiment

Online System

~100 MBytes/sec

Offline Farm, CERN Computer Ctr

Tier 0 +1

~2.5 Gbits/sec

Tier 1

FNAL Center

UK Center

Italy Center

France Center

...

~0.6-2.5 Gbits/sec

Tier 2

Tier2 Center

Center

Center

Center

~622 Mbits/sec

Tier 3

Institute

Institute

Institute

Institute

Physics data cache

100 - 1000 Mbits/sec

Workstations

Tier 4

Data flow shown in this demo

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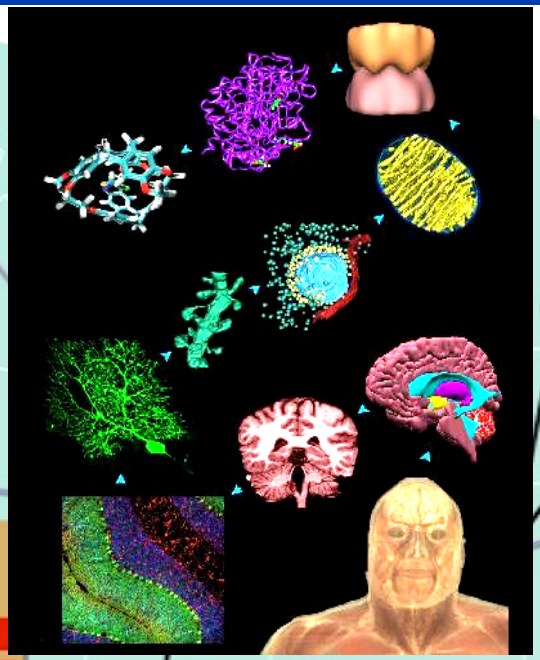
Source: Harvey Newman, Caltech

NIH is Creating a Federated Repository Biomedical Informatics Research Network



Northern Lights Network
University of Minnesota

Abilene
University of Iowa

Nox
Harvard I
Harvard II

Abilene
Stanford

CalREN-2
Caltech
UCLA
Irvine
NCMIR
UCSD II

BIRN Central NOC
SDSC

Abilene
LANL
University of New Mexico

NCNI
Duke I
Duke II
UNC

Mouse
Brain Morphology
Functional Imaging/Human
Abilene Backbone

NIH Plans to Expand BIRN to Other Organs and Many Laboratories

National Center For Research Resources

Part of the UCSD CRBS

Center for Research on Biological Structure

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NBCR

NPACI

NCMIR
NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH
at San Diego, an NIH supported resource center

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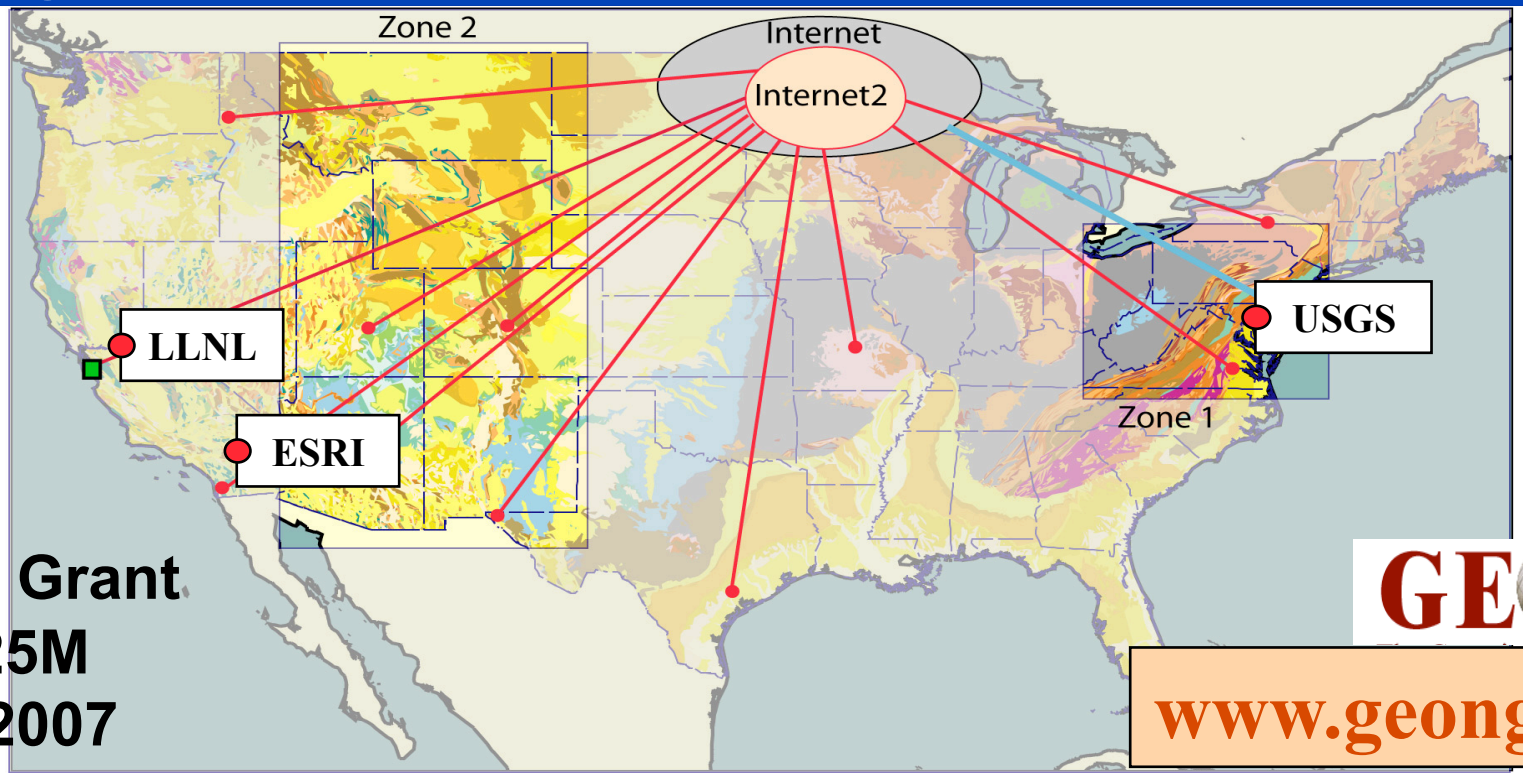
GEON
Cyberinfrastructure for the Geosciences



NSF ITR Grant
$11.25M
2002-2007

GEON

www.geongrid.org

IT: SDSC, Penn State, San Diego State University

Geosciences: Arizona State University, Bryn Mawr College, Cornell University, Rice University, UNAVCO, University of Arizona, University of Idaho, University of Missouri, University of Texas El Paso, University of Utah, Virginia Tech

Education and Outreach: DLESE, Cornell, UNAVCO

Agency Partners: USGS, Livermore Labs

Industry Partners: ESRI, GeoFusion, IBM

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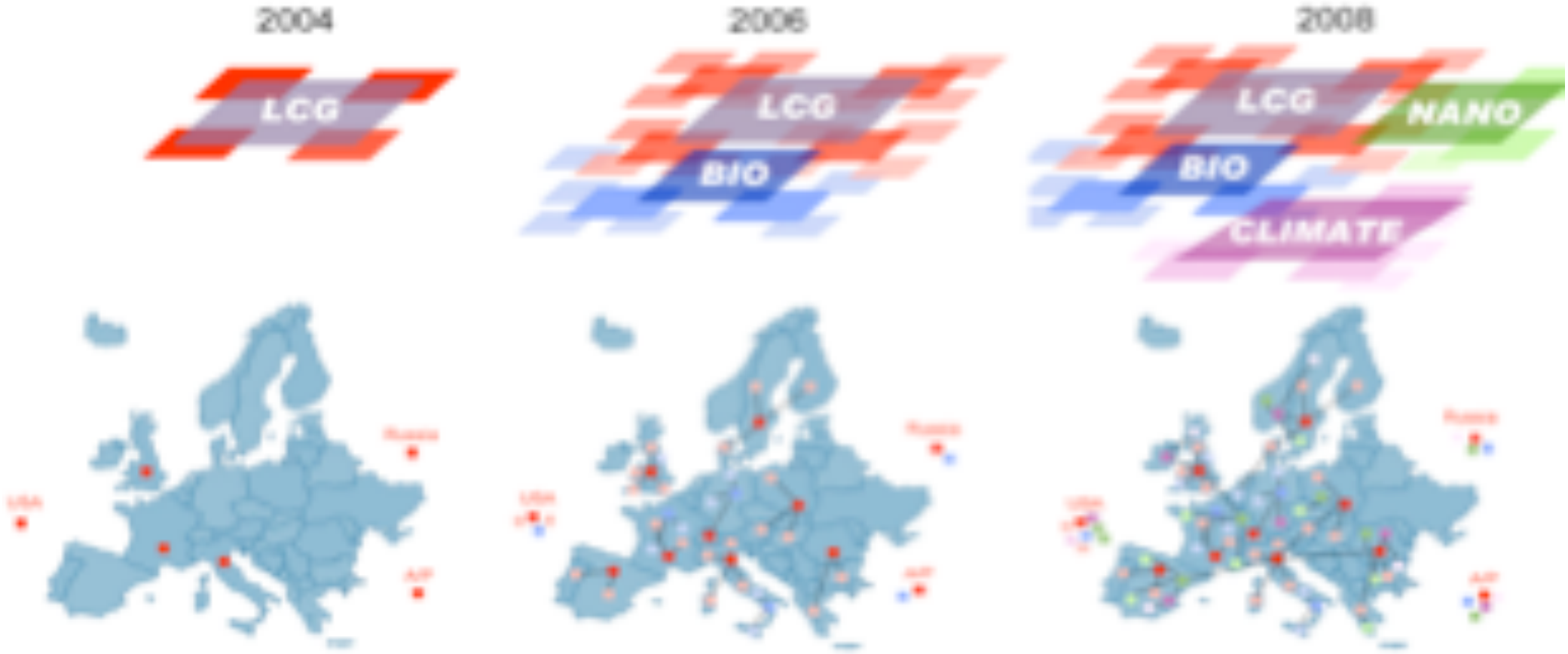
The European Data Grid
A Universal Information Infrastructure



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New Technologies to Improve the Information Infrastructure

- Dedicated Optical Networks
- Distributed Storage Fabric
- Multi-Mega Pixel Images
- Interactive Volume Visualization
- Integration of Aerial and Satellite Imagery
- Realtime Data fusion of Sensor Nets
- Collaboration Systems

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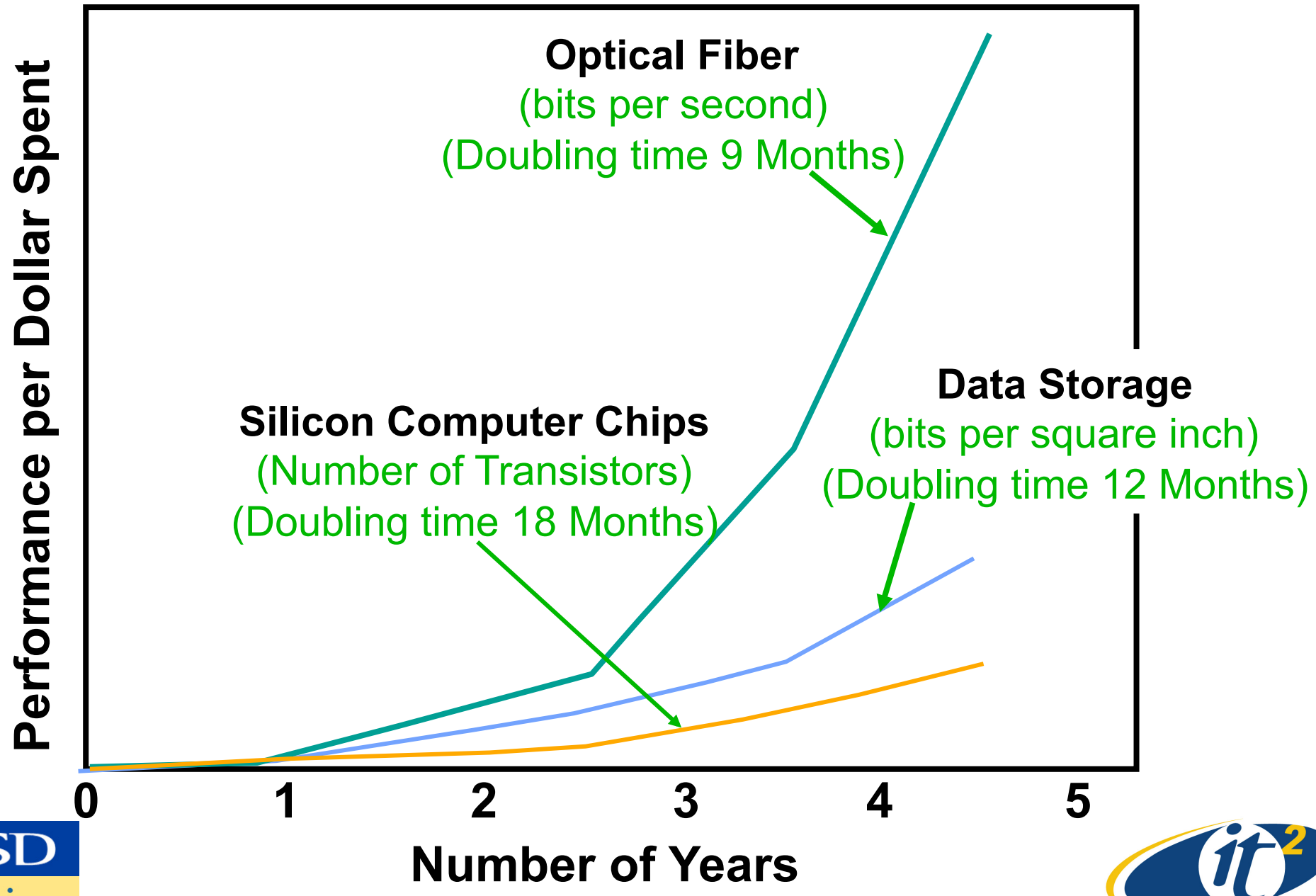
Why Optical Networks Are Emerging as the 21st Century Driver



Scientific American, January 2001

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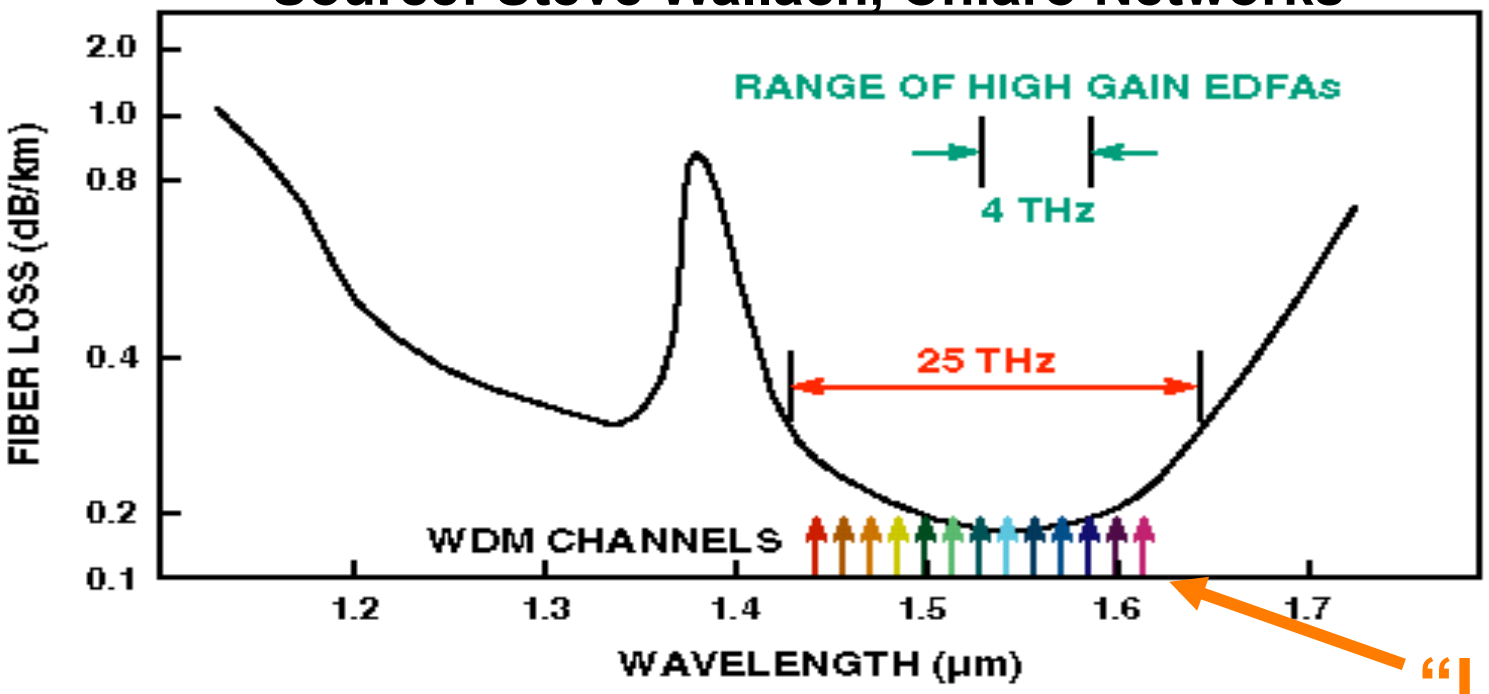
Parallelism Has Come to Optical Networking

WAVELENGTH DIVISION MULTIPLEXING (WDM)

- EXPLOITS
  - ENORMOUS BANDWIDTH OF SILICA FIBER
  - HIGH-GAIN WIDEBAND OPTICAL AMPLIFIERS

Source: Steve Wallach, Chiaro Networks



CHIARO

"Lambdas"

Parallel Lambdas Will Drive This Decade The Way Parallel Processors Drove the 1990s

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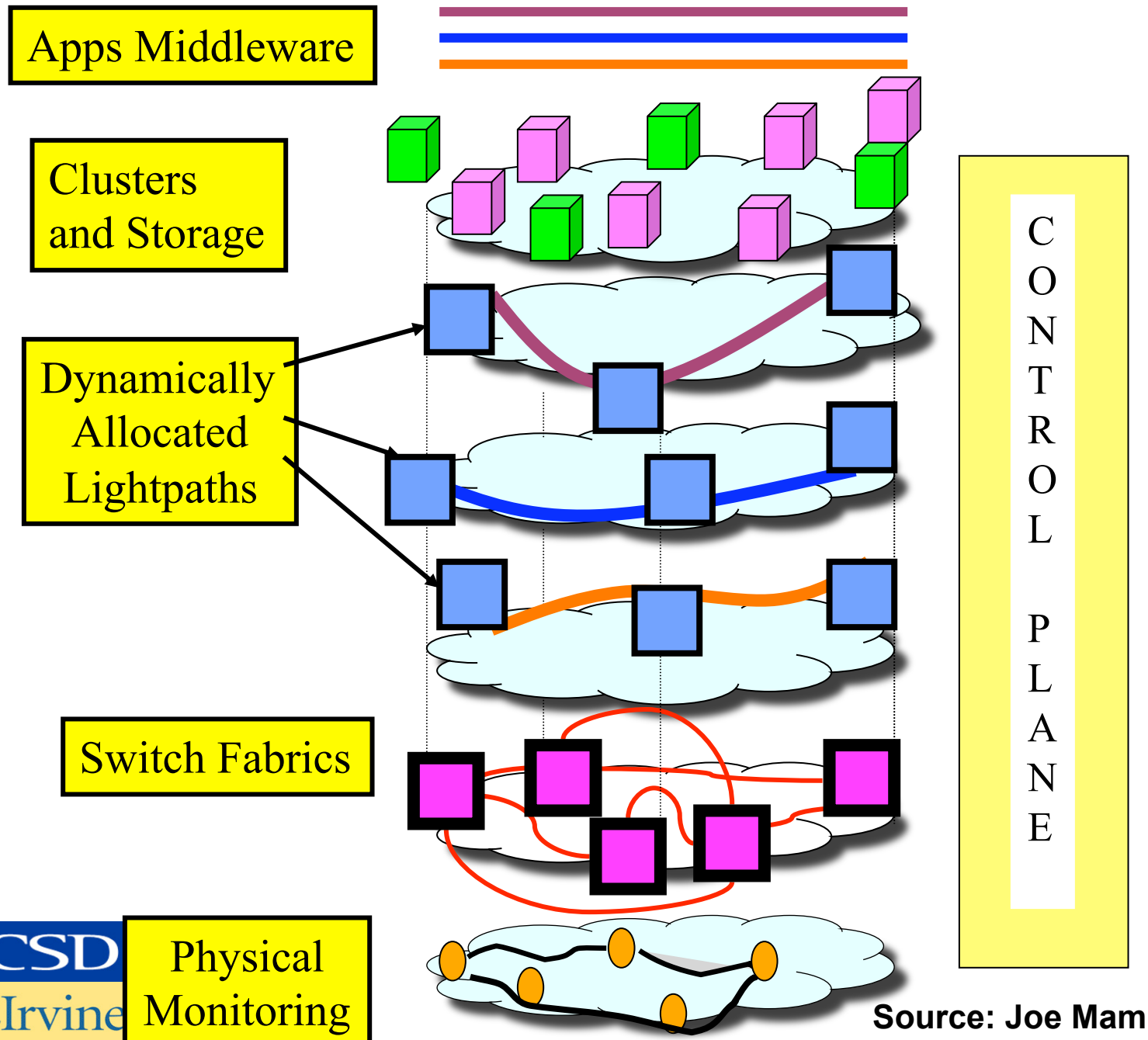
A LambdaGrid Will Create an Optical Fabric as the Backbone of an e-Science Network



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Source: Joe Mambretti, NU

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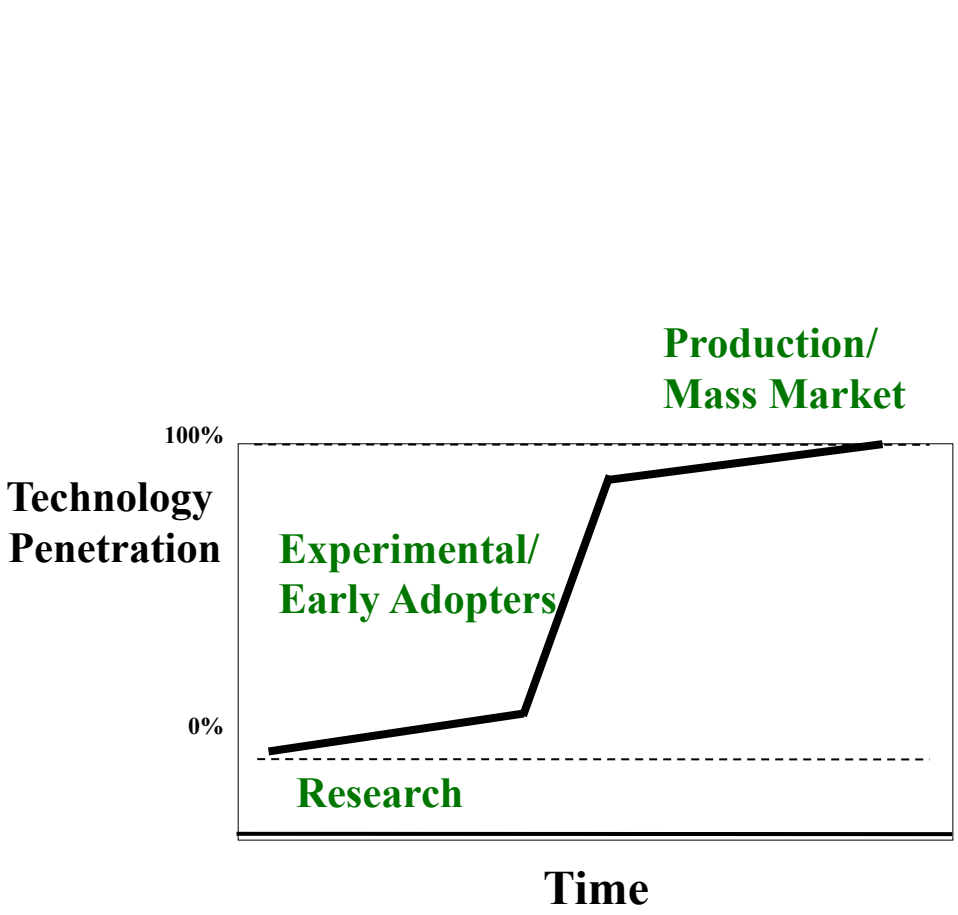
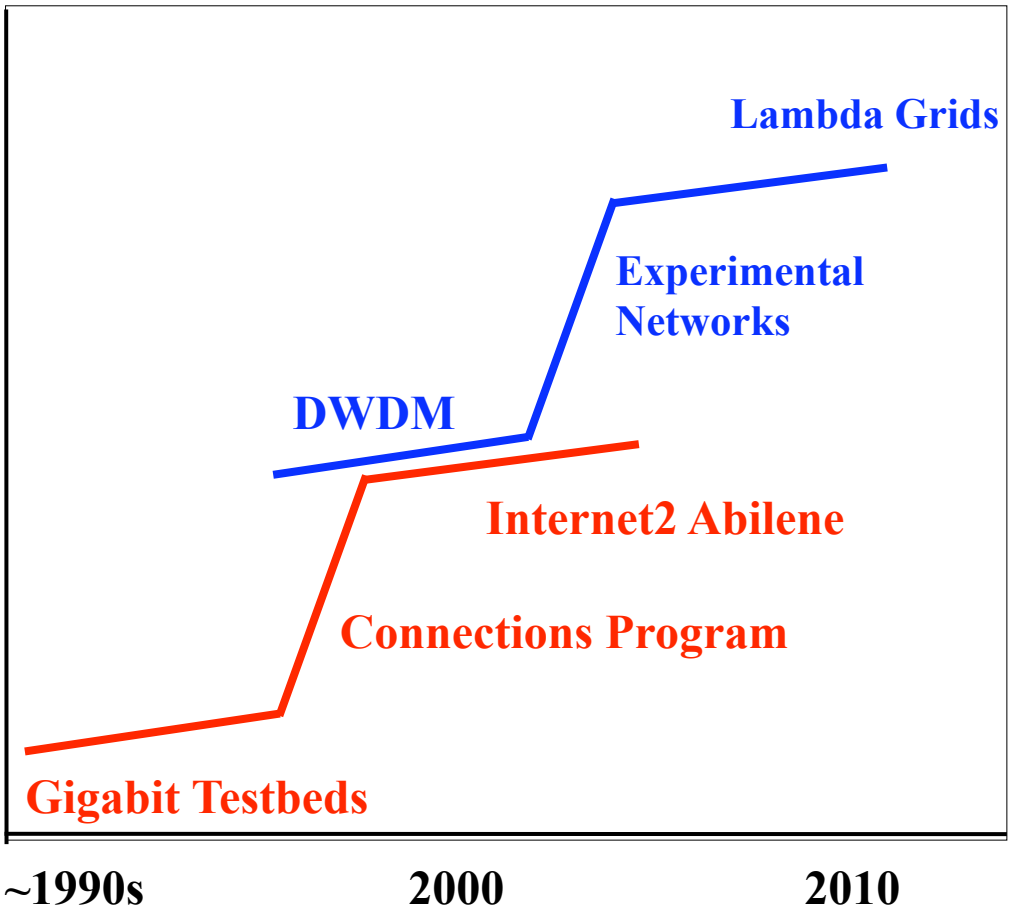
The Next S-Curves of Networking Exponential Technology Growth



Technology S-Curve



Networking Technology S-Curves

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National Light Rail Footprint
Layer 1 Topology

15808 Terminal, Regen or OADM site
(OpAmp sites not shown)

Fiber route

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John Silvester, Dave Reese, Tom West-CENIC

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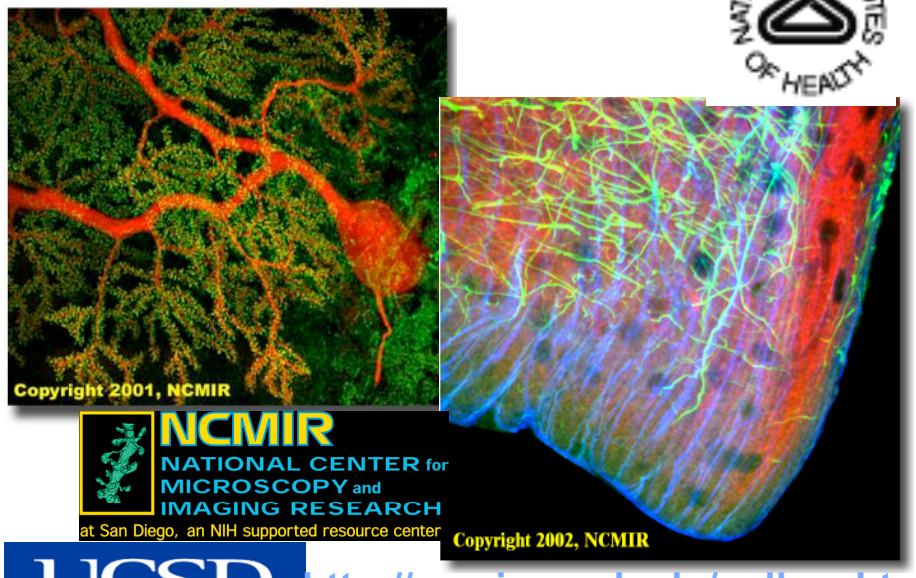
OptIPuter Data-Intensive Application Drivers: BioScience and GeoScience

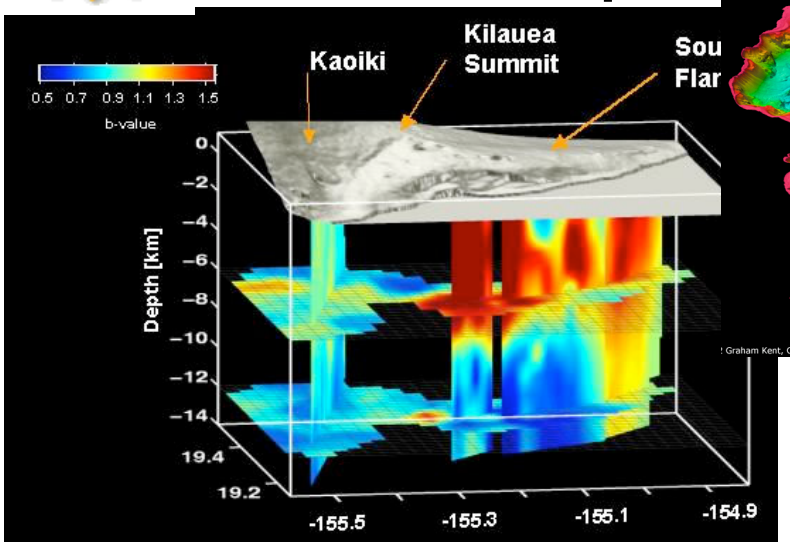
- **NSF Large Information Technology Research Proposal**
  - **UCSD and UIC Lead Campuses—Larry Smarr PI**
  - **USC, UCI, SDSU, NW Partnering Campuses**
- **Industrial Partners: IBM, Telcordia/SAIC, Chiaro, Calient**
- **$13.5 Million Over Five Years**

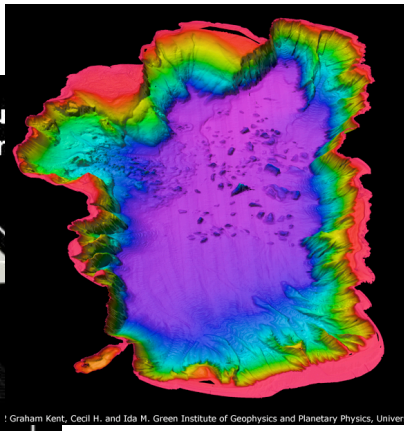
NIH Biomedical Informatics Research Network



http://ncmir.ucsd.edu/gallery.html

NSF EarthScope





siovizcenter.ucsd.edu/library/gallery/shoot1/index.shtml

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Science Drivers for a Radical New Architecture—The OptIPuter

- **Neuro & Earth Sciences**
  - Each Data Object is 3D and Gigabytes
  - Data in Distributed Federated Repository
  - Want to Interactively Analyze and Visualize
  - Need Multiple Disciplinary Specialists
- **Science Requirements for Dedicated Link**
  - Computing Requirements → PC Clusters
  - Communications → Dedicated Lambdas
  - Data → Large Lambda Attached Storage
  - Visualization → Collaborative Volume Algorithms

Goal:
Punch a Hole Through the Internet Between Researcher's Lab and Remote Data!

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The OptIPuter Philosophy

Bandwidth is getting cheaper faster than storage.
Storage is getting cheaper faster than computing.
Exponentials are crossing.

"A global economy designed
to waste transistors, power, and silicon area
-and conserve bandwidth above all-
is breaking apart and reorganizing itself
to waste bandwidth
and conserve power, silicon area, and transistors."
George Gilder Telecosm (2000)

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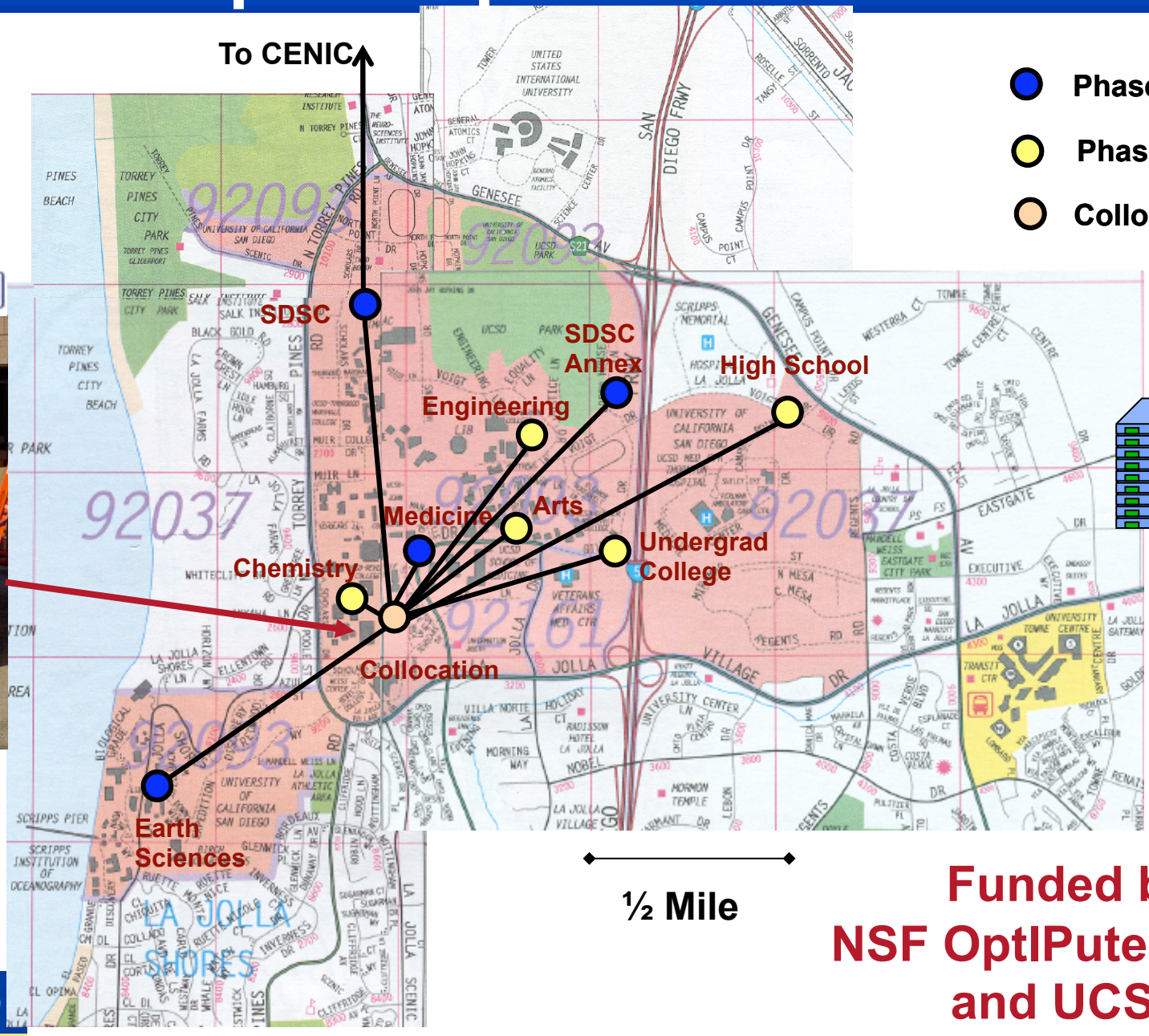
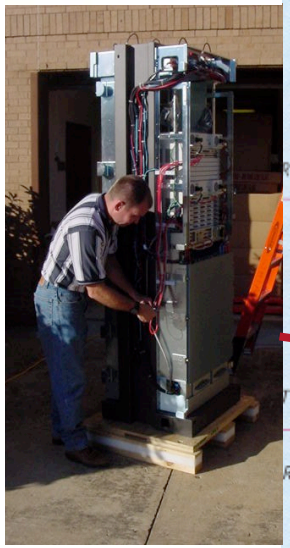
OptIPuter Dedicated Optical Fiber Campus Experimental Network

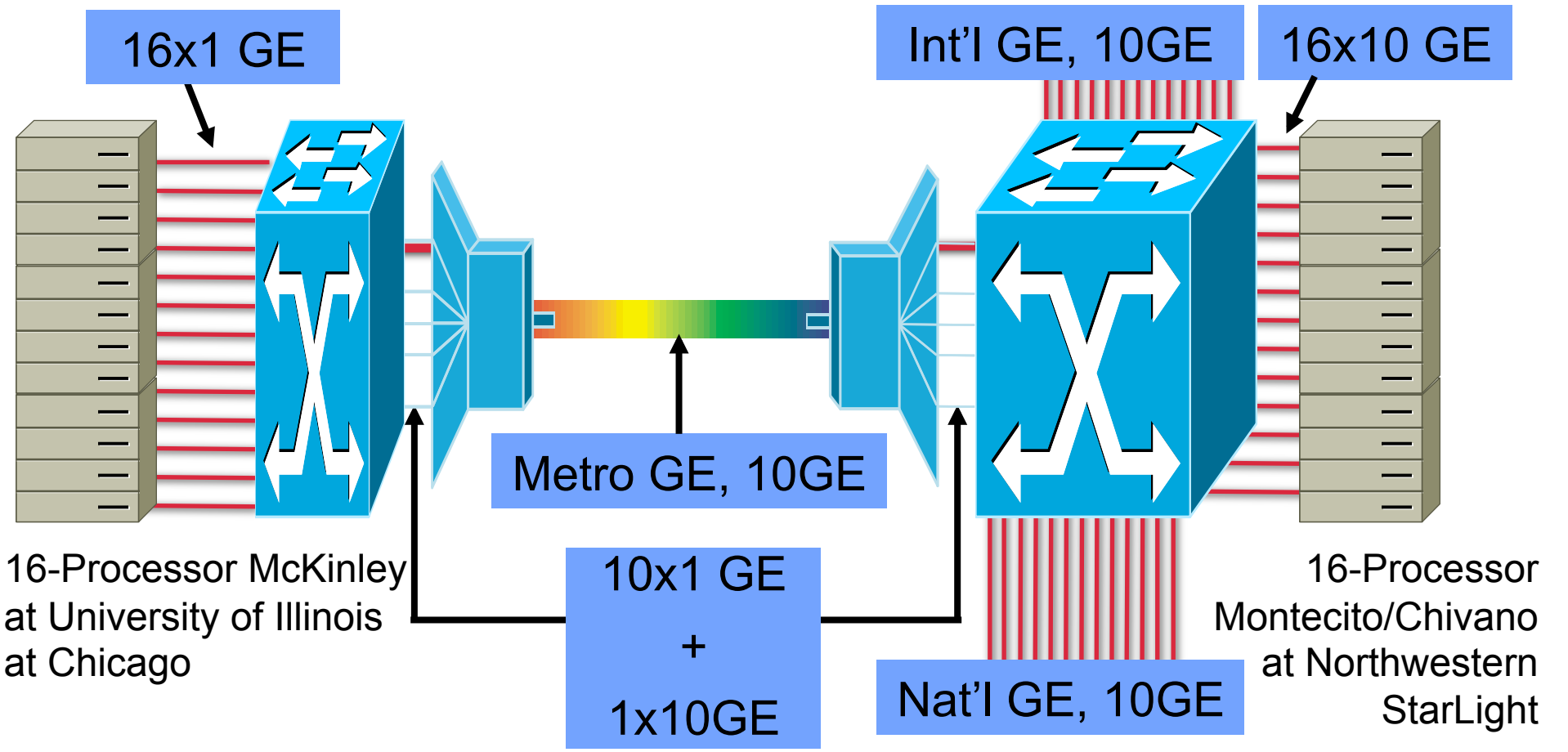




Funded by NSF OptIPuter Grant and UCSD

Source: Phil Papadopoulos, SDSC; Greg Hidley, Cal-(IT)²

Chicago Metro
Lambda Switching OptIPuter Laboratory



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Source: Tom DeFanti, UIC

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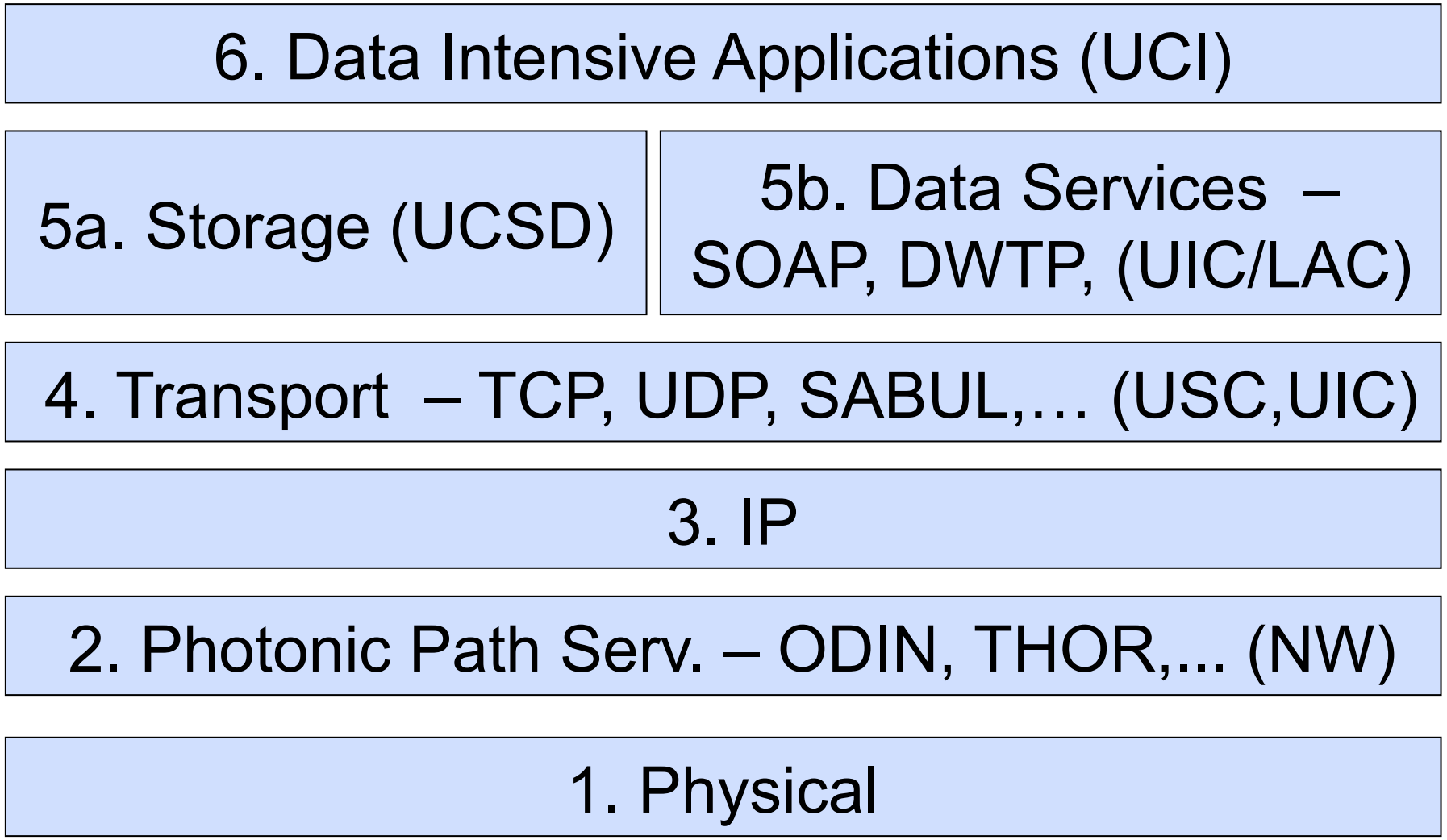
Photonic Data Services & OptIPuter



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Source: Robert Grossman, UIC/LAC

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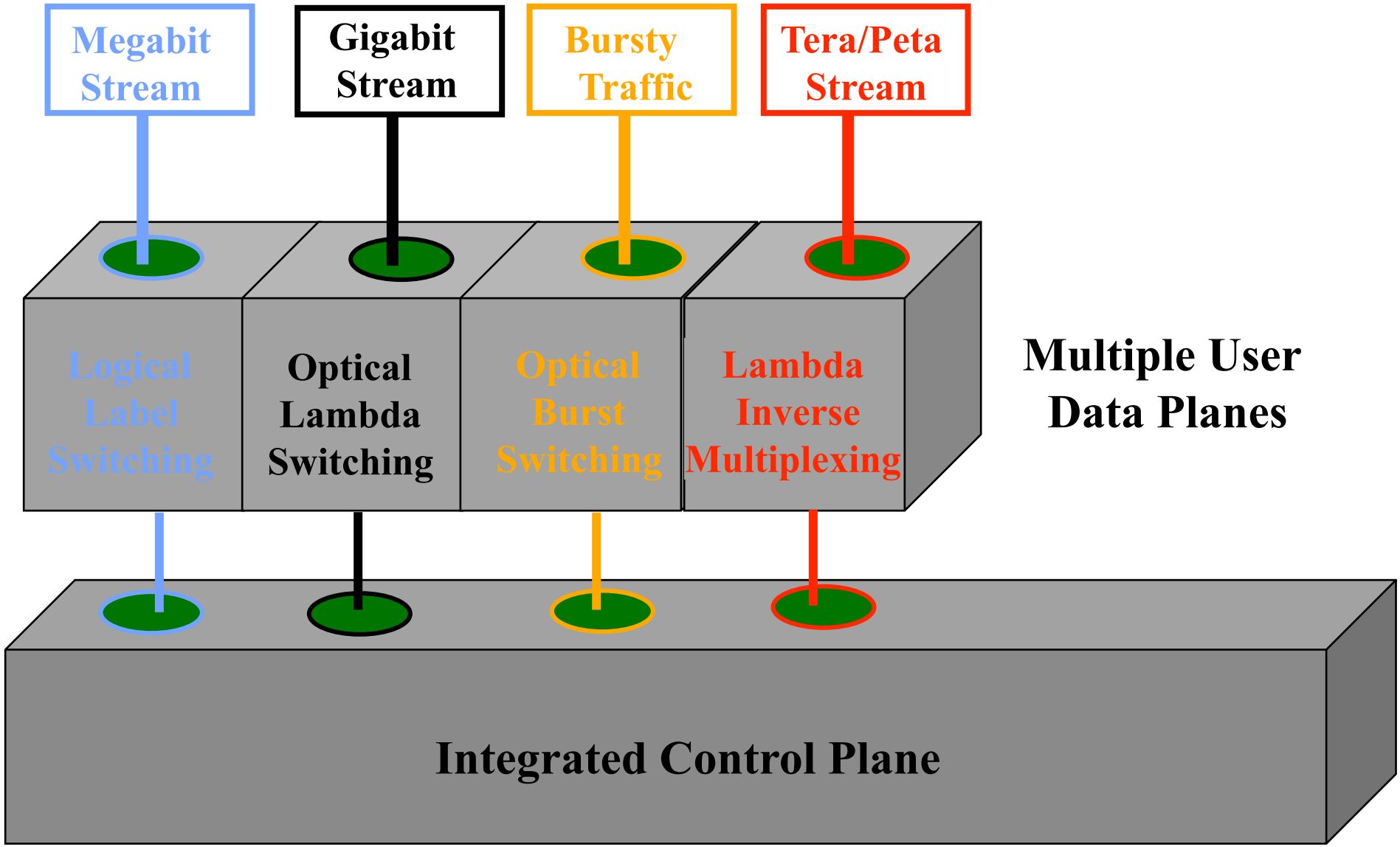
Research Into Integrated Optical Control Plane



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Source: Oliver Yu, UIC

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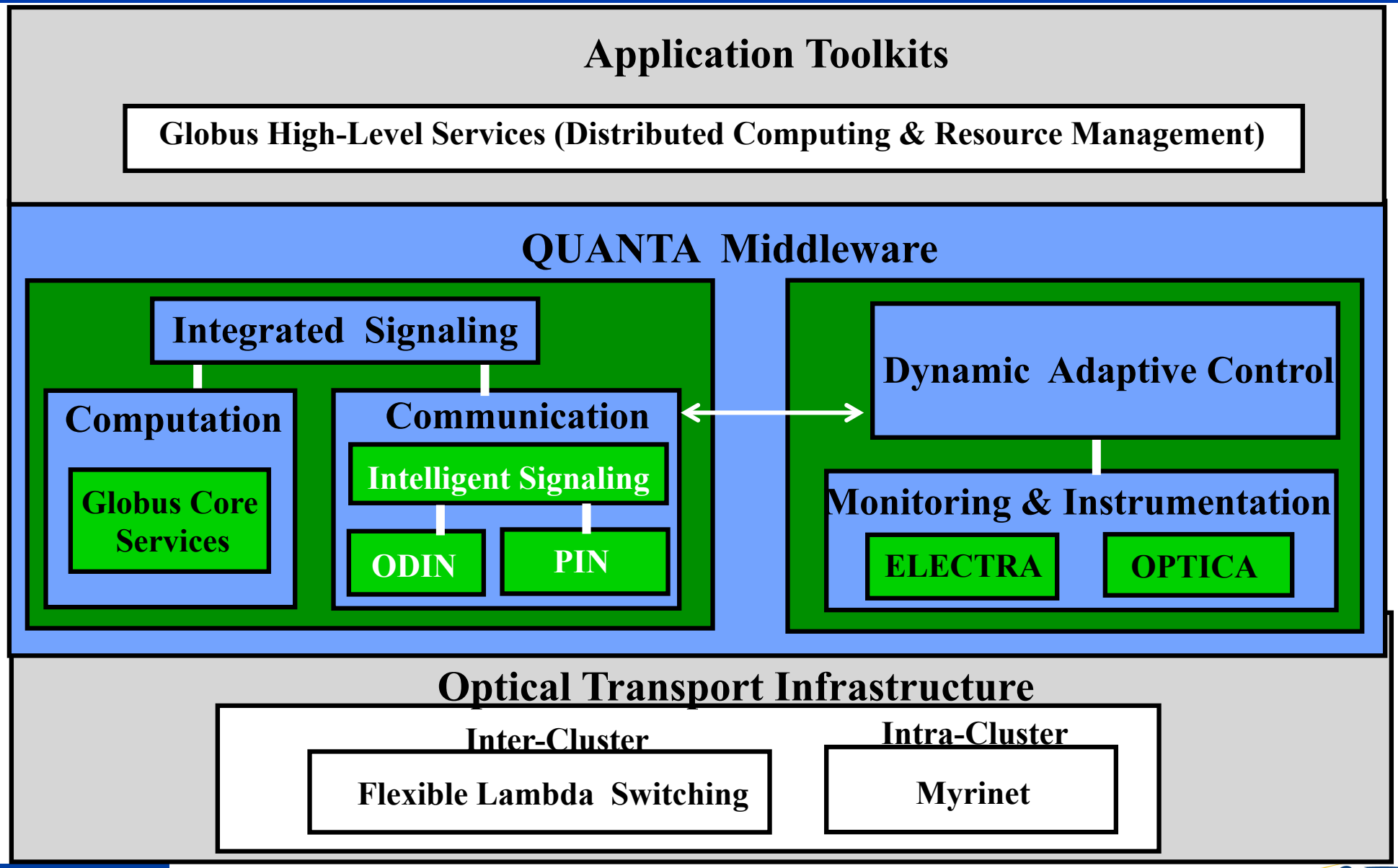
OptIPuter
QUANTA Middleware Architecture



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Source: Jason Leigh, Oliver Yu, UIC

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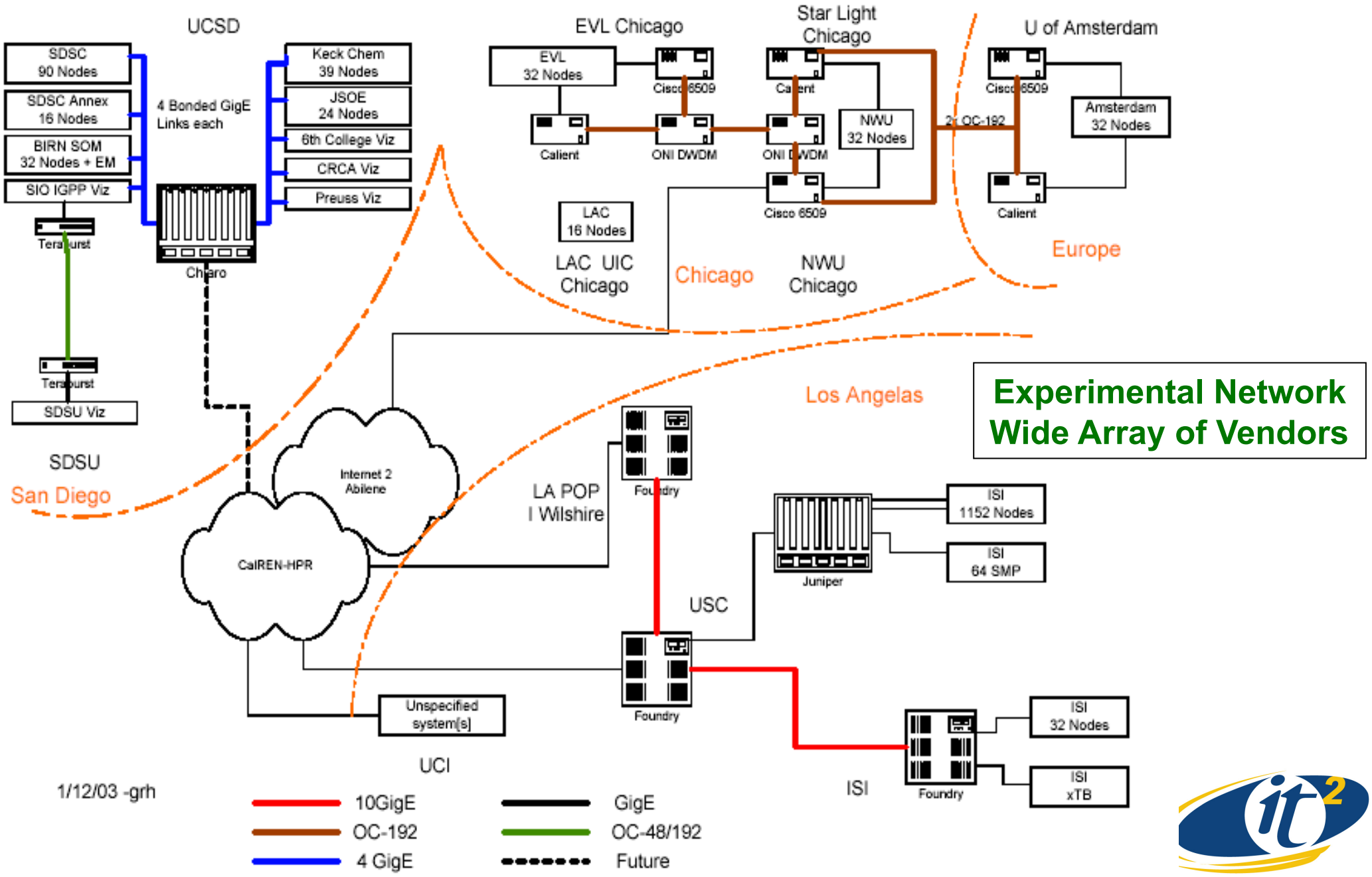
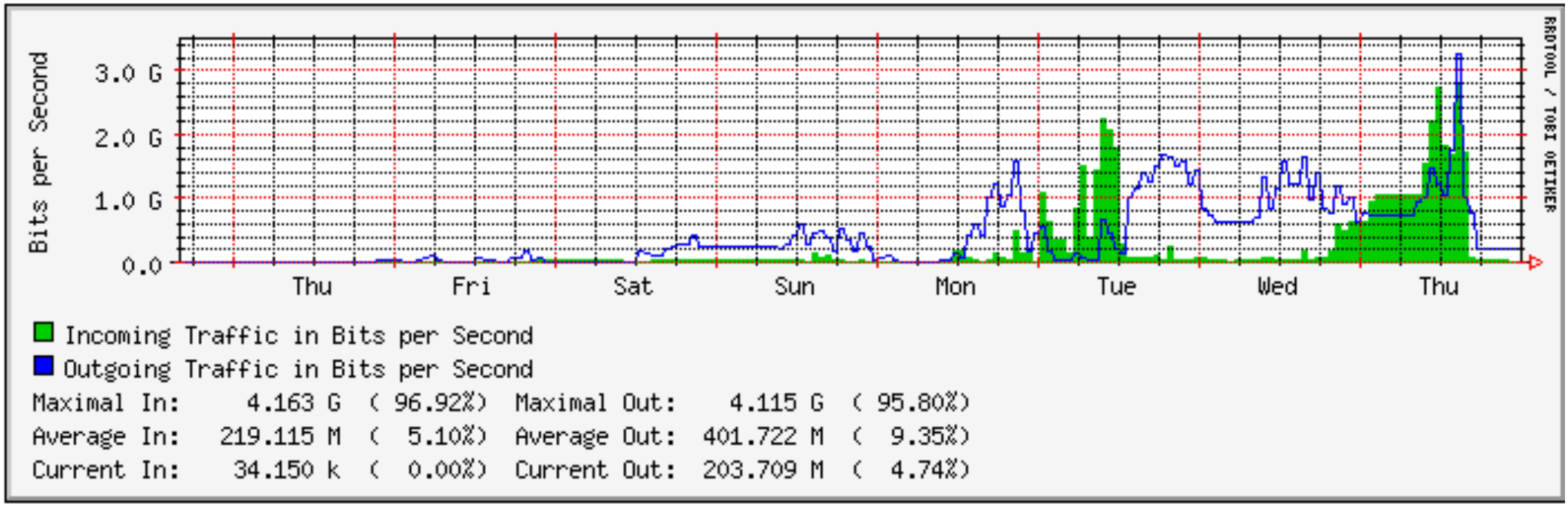
The OptIPuter 2003



Experimental Network
Wide Array of Vendors

iGrid 2002 Was Sustaining 1-3 Gigabits/s



Total Available Bandwidth Between Chicago and Amsterdam Was 30 Gigabit/s

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US Geological Survey – Earth Resources Observation Systems (EROS) Data Center

- **Landsat 7 Satellite Program**
  - Images at 30m Resolution
  - Each Scene is 115 x 105 miles
    - ~ 6000x6000 Pixels
    - 3.8 gigabits per Scene
    - 250 Scenes per Day
- **The Whole Earth**
  - 58,000 Scenes
  - 220 Terabits
- **Moving Just 1% of Earth**
  - on a 1 Gigabit Network ~ an Hour
  - GIS Scientists Need to Have LOTS of Gigabits per second!
- **EROS is Partnering with Cal-(IT)^2**

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Source: Jason Leigh, EVL, UI Chicago

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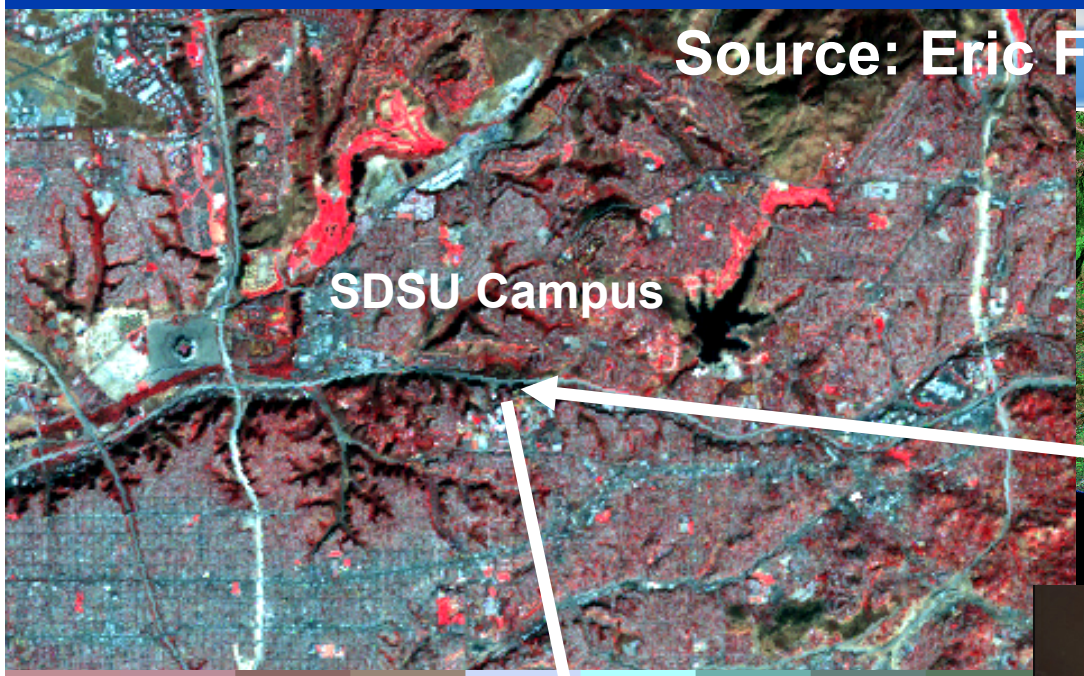
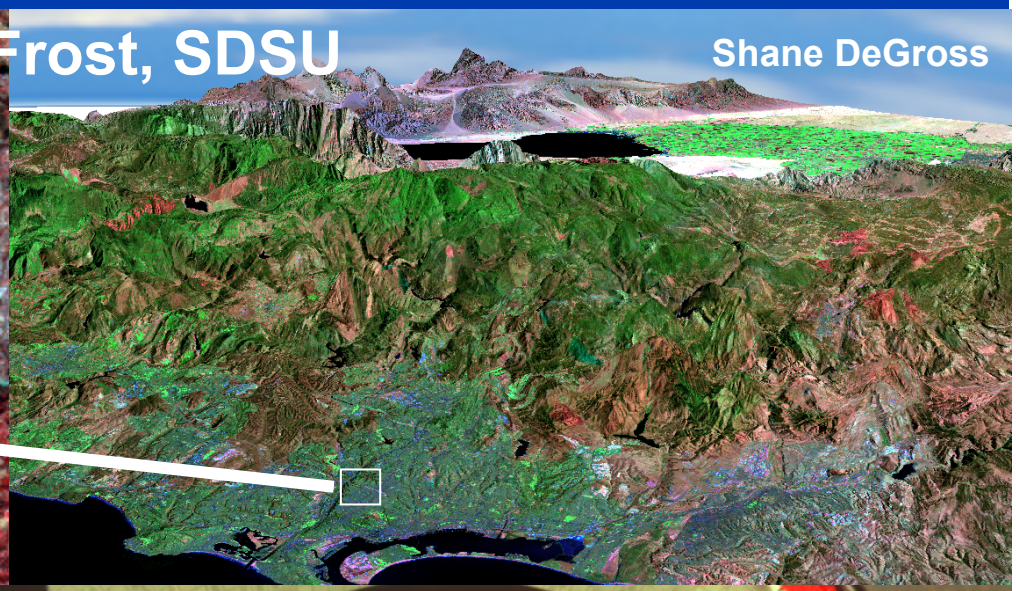
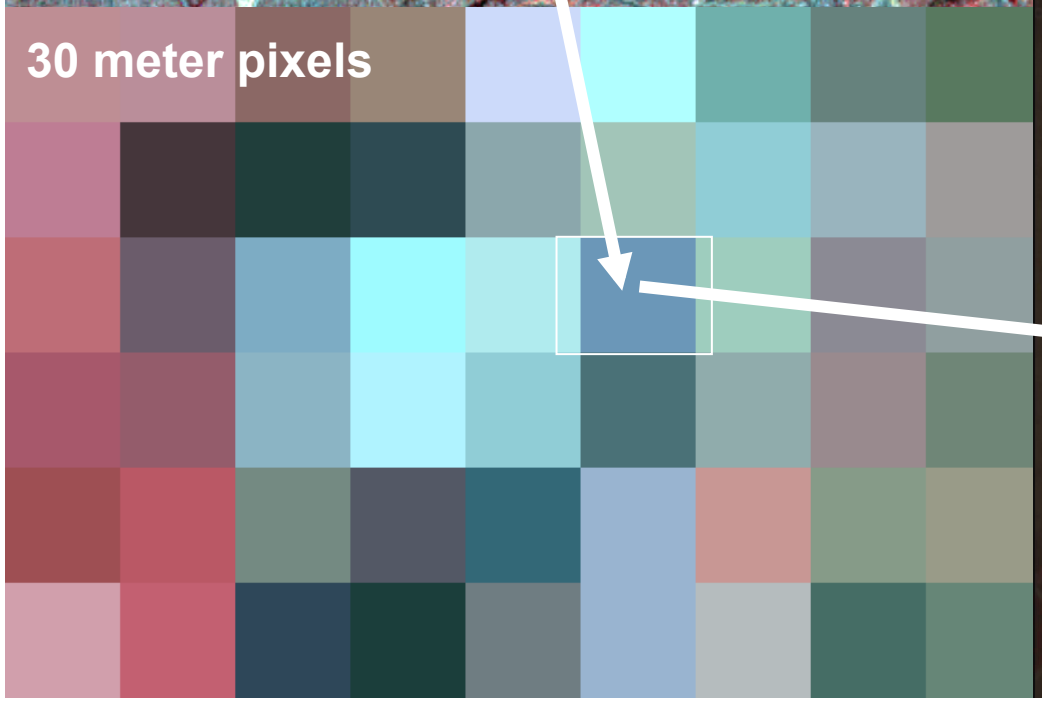
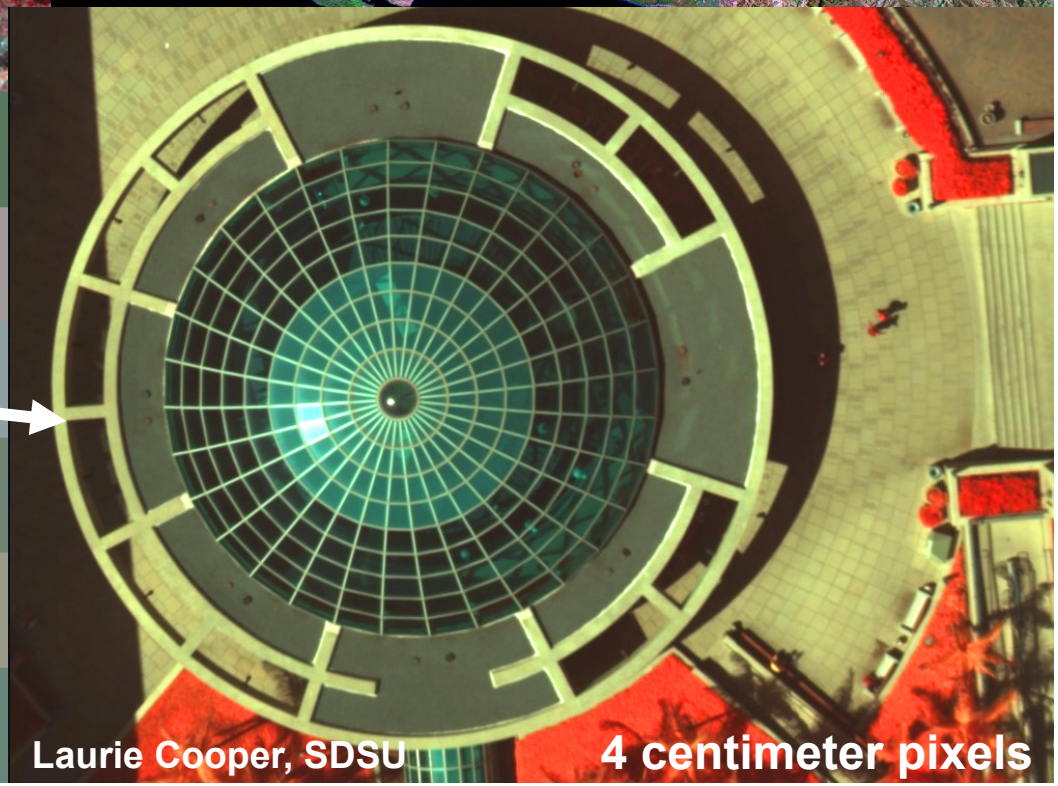
Today's Aerial Imaging is 10,000 Times More Detailed than Landsat 7 Satellite Images



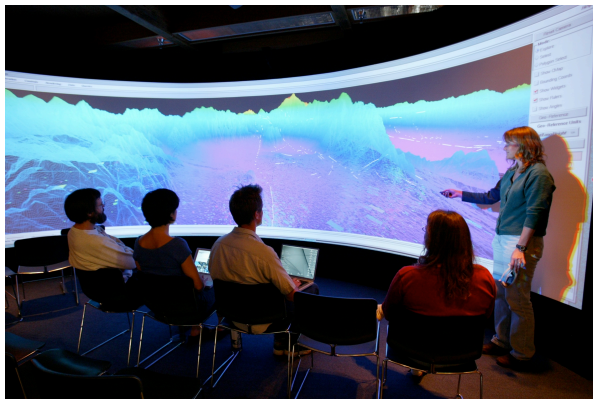






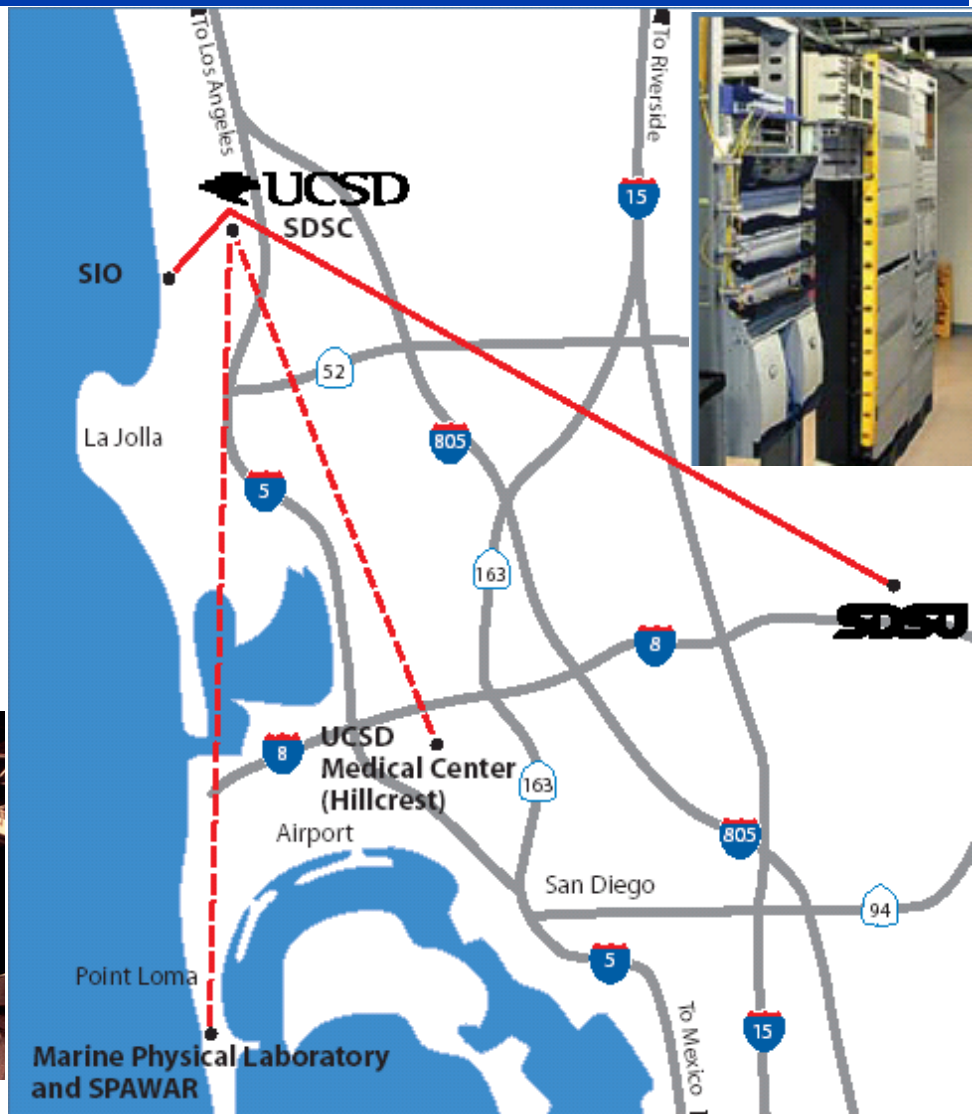
Remote Collaborative Visual Analysis of Large Datasets

- **Driven by SensorNets Data**
  - Real Time Seismic
  - Environmental Monitoring
  - Emergency Response
  - Distributed Corporations
- **Linked UCSD and SDSU**
  - Dedication March 4, 2002



UCSD ⟷ SDSU

44 Miles of Cox Fiber



Cox, Panoram, SAIC, SGI, IBM, TeraBurst Networks SD Telecom Council

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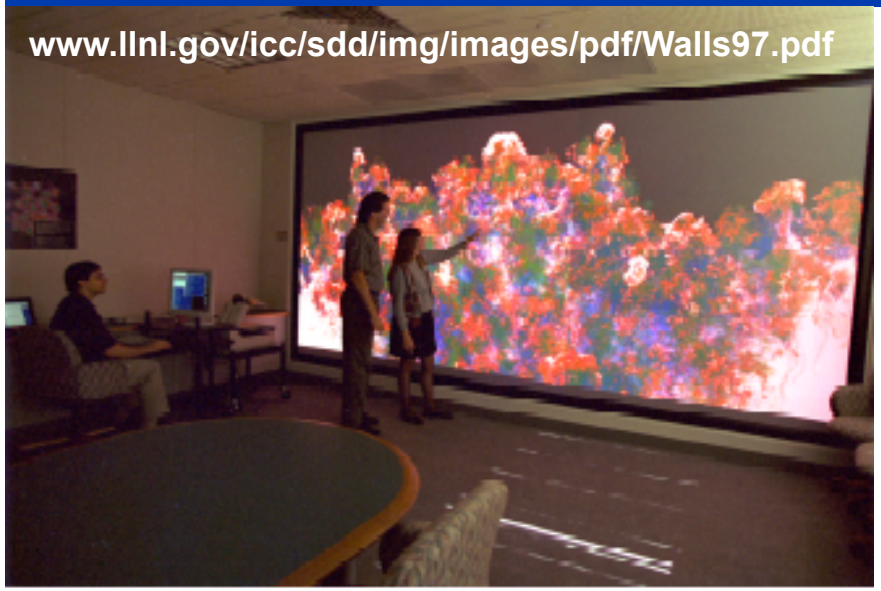
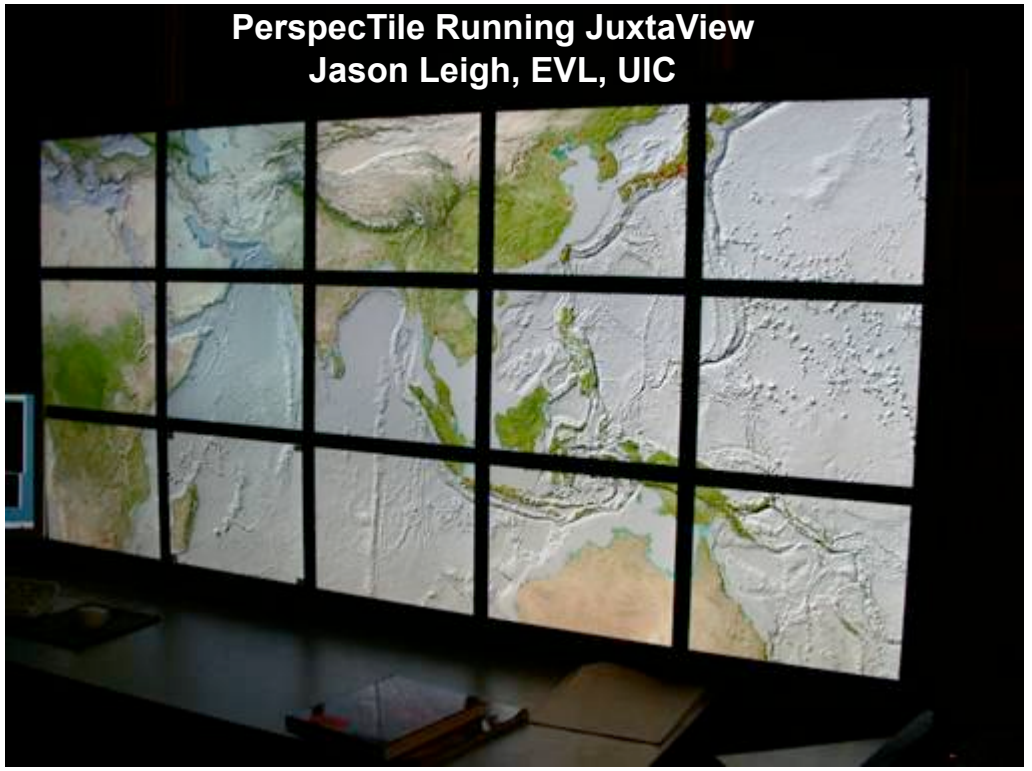
Many Groups Are Building Tiled Displays For Large 2 and 3D Image Viewing





LCD Panels

Video Projectors

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Each 3x5~20 Megapixels Total

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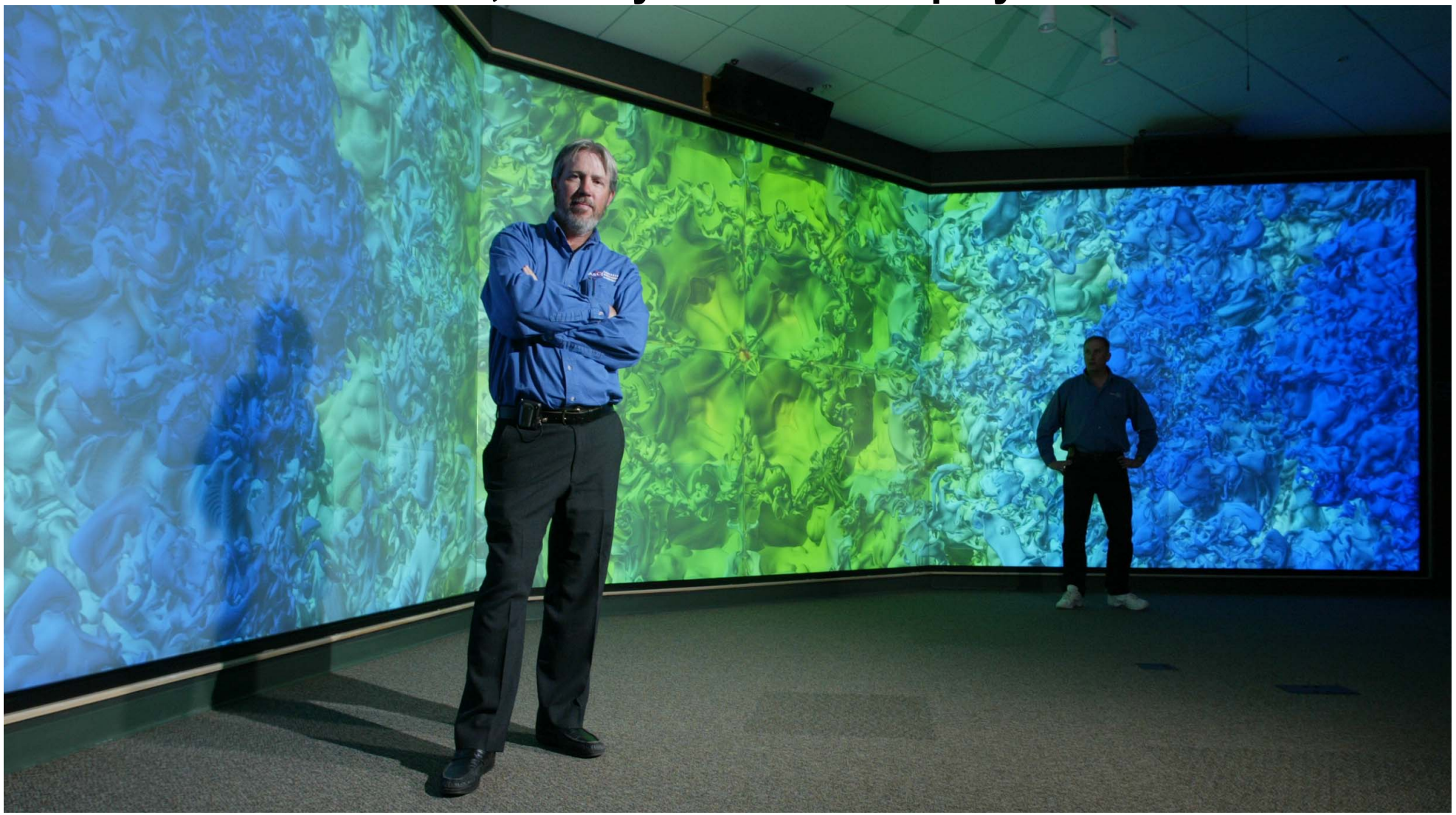
Current Bleeding Edge--60 Million Pixels Driven By Commodity PC Cluster!

At 15 Frames/s, The System Can Display 2.7 GB/Sec



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Source: Philip D. Heermann, DOE ASCI Program

Sandia National Laboratories

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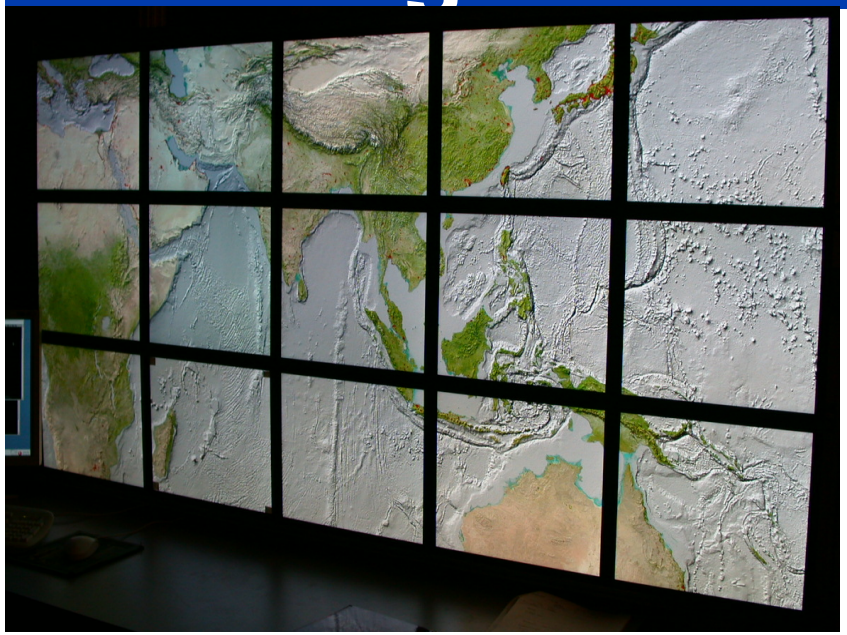
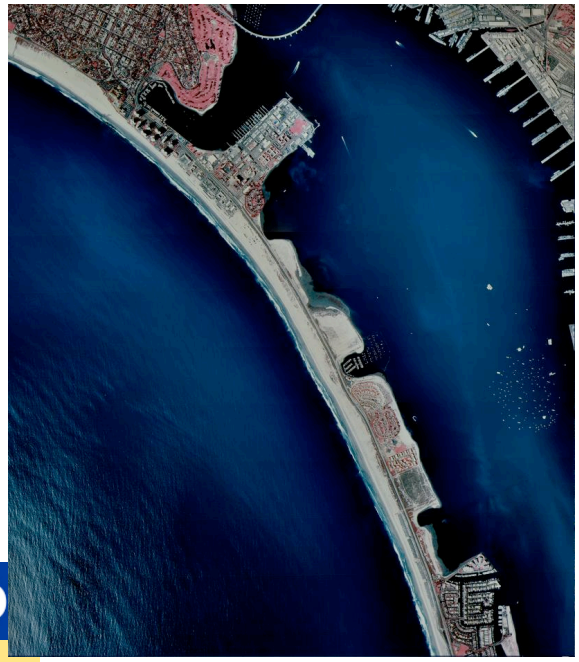
Building a Digital San Diego Linking GIS Data to High Res Imagery





- **JuxtaView**
  - Digital Montage Viewer For Perspectile LCD Wall
  - 6000x3000 Pixel Resolution
- **Display Is Powered By**
  - 16 PCs With Graphics Cards
  - 2 Gigabit Networking Per PC
- **USGS EROS Center Data:**
  - 133 Urban Areas:
    - One Foot Resolution
    - 100,000 x 100,000 Pixels for 20 sq.mile Urban Area

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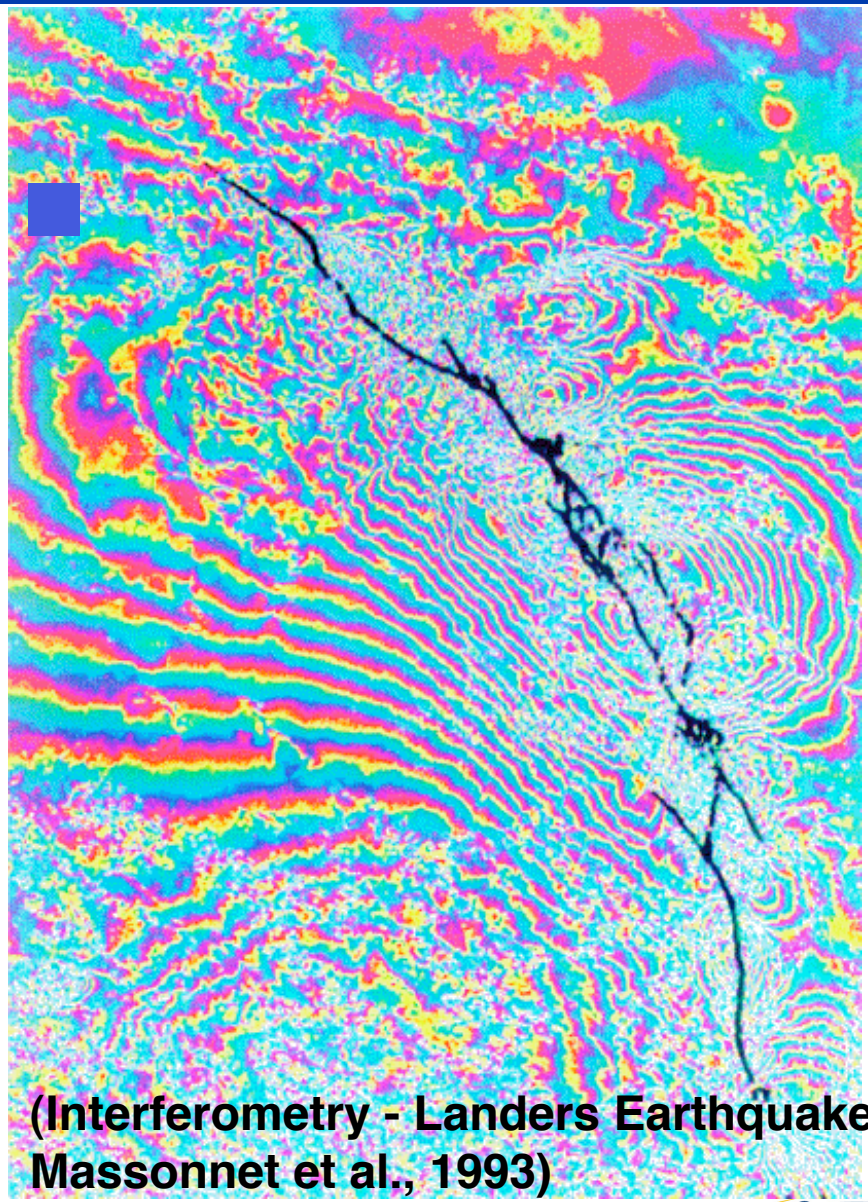
Source: Jason Leigh, EVL, UIC; USGS EROS

it²

Integrating Real-Time Geo Changes with SAR and GPS Geodesy

- Western North America Crustal Dynamics Research: WInSAR Consortium
- Monitor Strain Accumulation And Release Along The North American/Pacific Plate Boundary With An Emphasis On The San Andreas Fault Zone
- Crustal Dynamics Community Energized By Interferograms Of 1992 Landers Earthquake
- Future-Need Near Near-time Access To SAR Data



(Interferometry - Landers Earthquake Massonnet et al., 1993)

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Source: David T. Sandwell, SIO, UCSD

it²

Current And Future Earth- Observing SAR Missions

Data acquisition rates: ~150 Mb/s

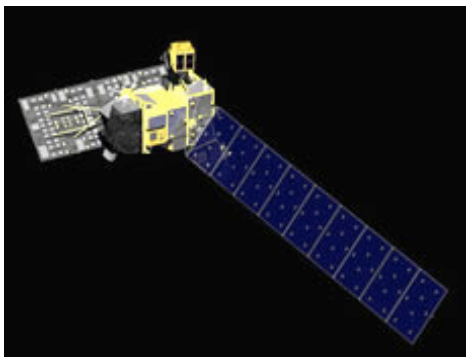
Mission lifetime: 5-10 years

Acquisition/processing time: 1/100

Envisat, 2002-

ERS-1/2, 1992-1999, 1995-

Radarsat-2, 2004-



ALOS, 2004-

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From Telephone Conference Calls to Access Grid International Video Meetings

Can We Create Realistic Telepresence Using Dedicated Optical Networks?

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Access Grid Lead-Argonne
NSF STARTAP Lead-UIC's Elec. Vis. Lab

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Planning for Optically Linking Crisis Management Control Rooms in California

California Office of Emergency Services, Sacramento, CA

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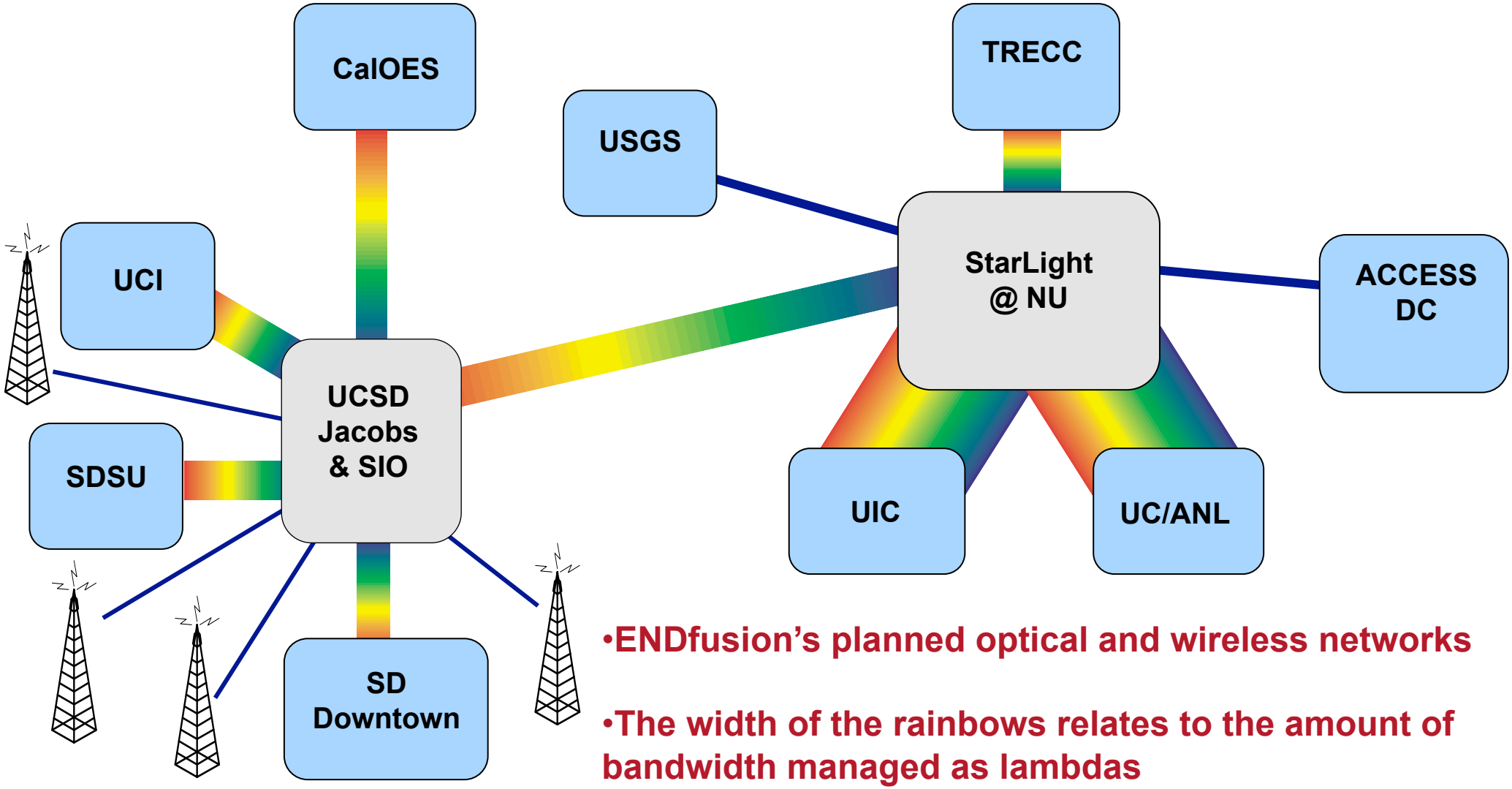
ENDfusion: End-to-End Networks for Data Fusion in a National-Scale Urban Emergency Collaboratory



- ENDfusion's planned optical and wireless networks
- The width of the rainbows relates to the amount of bandwidth managed as lambdas
- Blue lines are conventional networks

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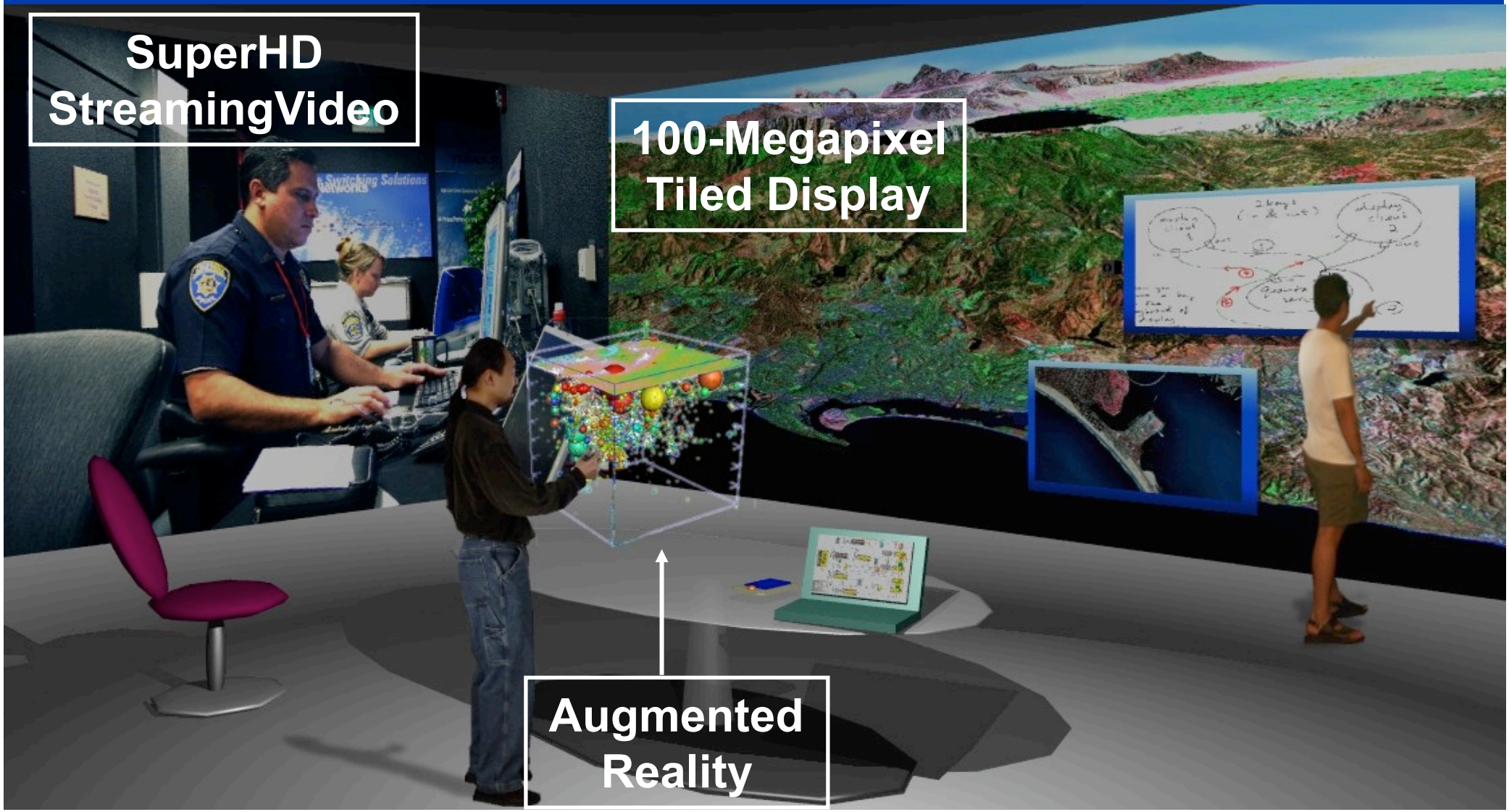
Source: Maxine Brown, EVL, UIC

it2

A High Definition Access Grid as Imagined In 2007 In A HiPerCollab



ENDfusion Project

Source: Jason Leigh, EVL, UIC

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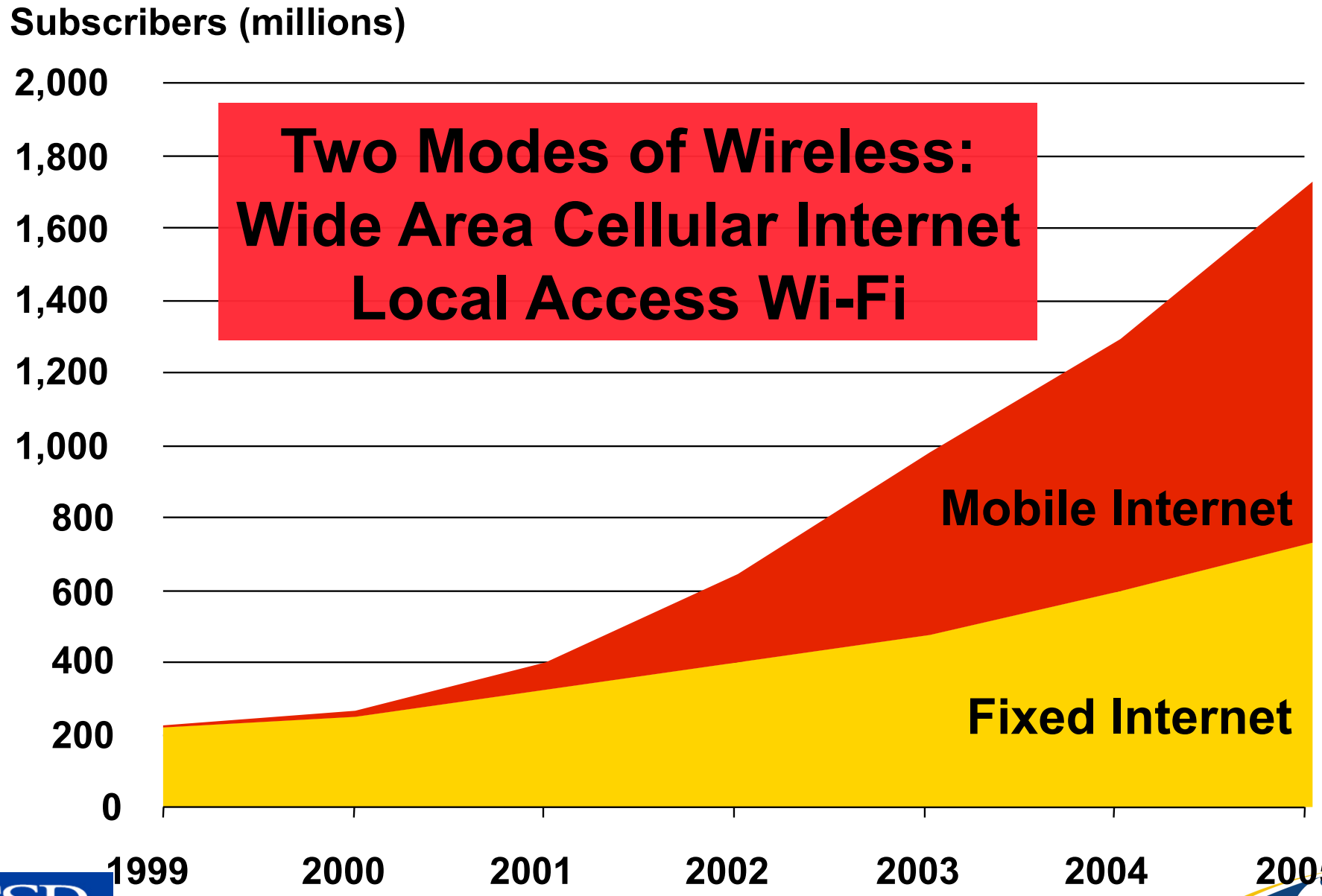
Transitioning to the "Always-On" Mobile Internet



Source: Ericsson

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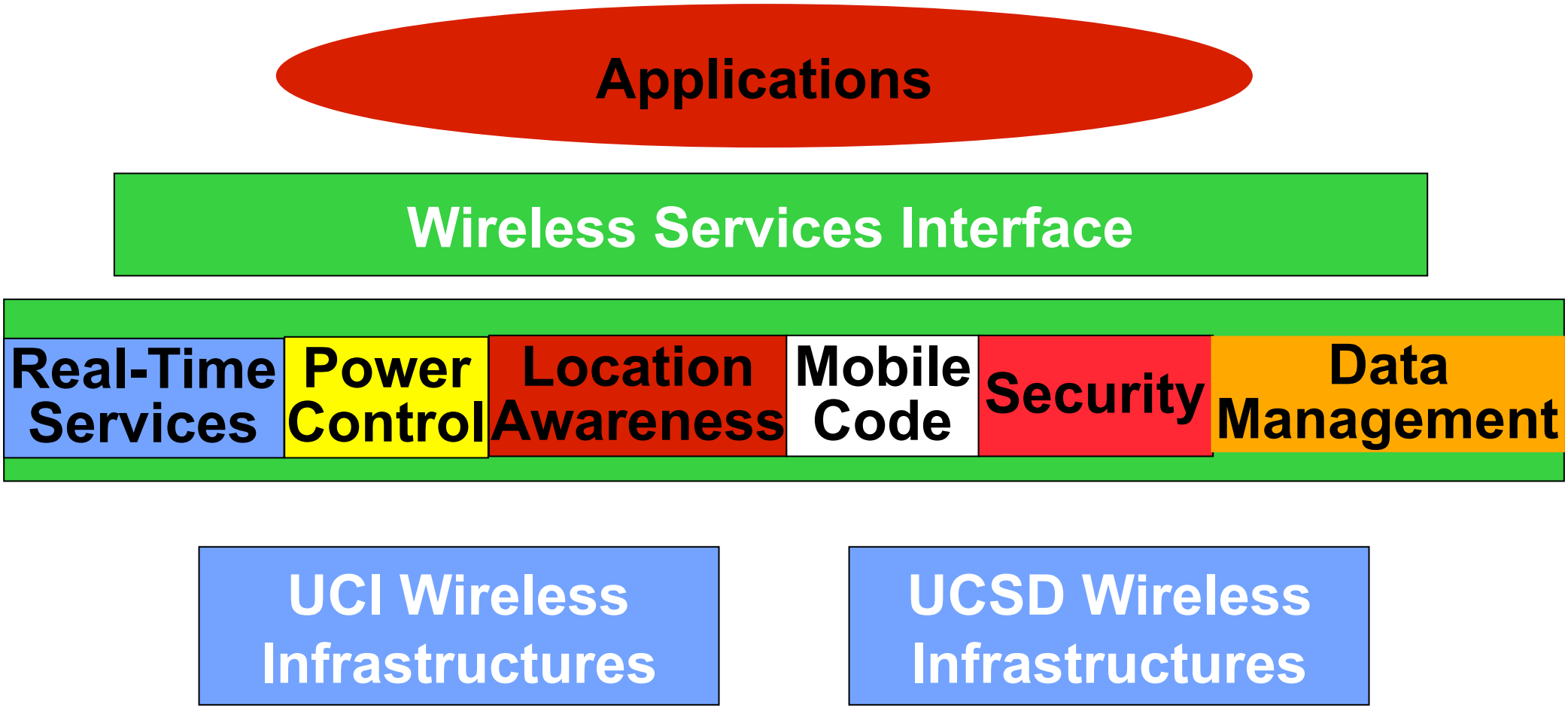
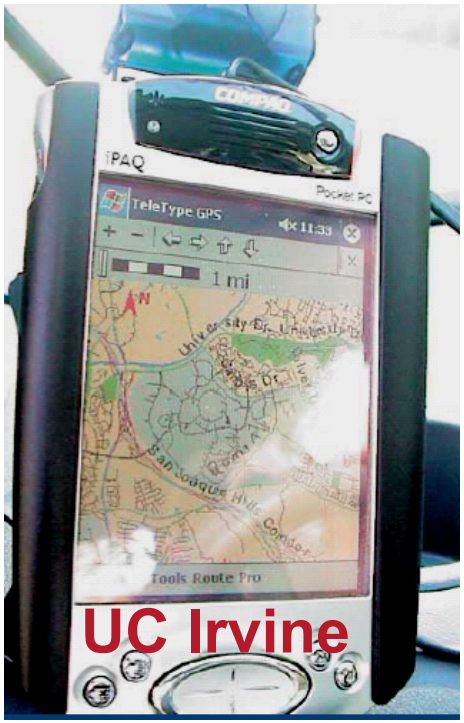
Required Wireless Services Middleware



Using Students to Invent the Future of Widespread Use of Wireless Devices

- **Broadband Internet Connection via Wireless Wi-Fi**
  - **Over 600 Access Points on the Campus**
- **Year- Long "Living Laboratory" Experiment 2001-02**
  - **500 Computer Science & Engineering Undergraduates**
- **300 Entering UCSD Sixth College Students—Fall 2002**
- **Experiments with Geo-Location and Interactive Maps**



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Cal-(IT)^2 Team: Bill Griswold, Gabriele Wienhausen, UCSD; Rajesh Gupta, UCI

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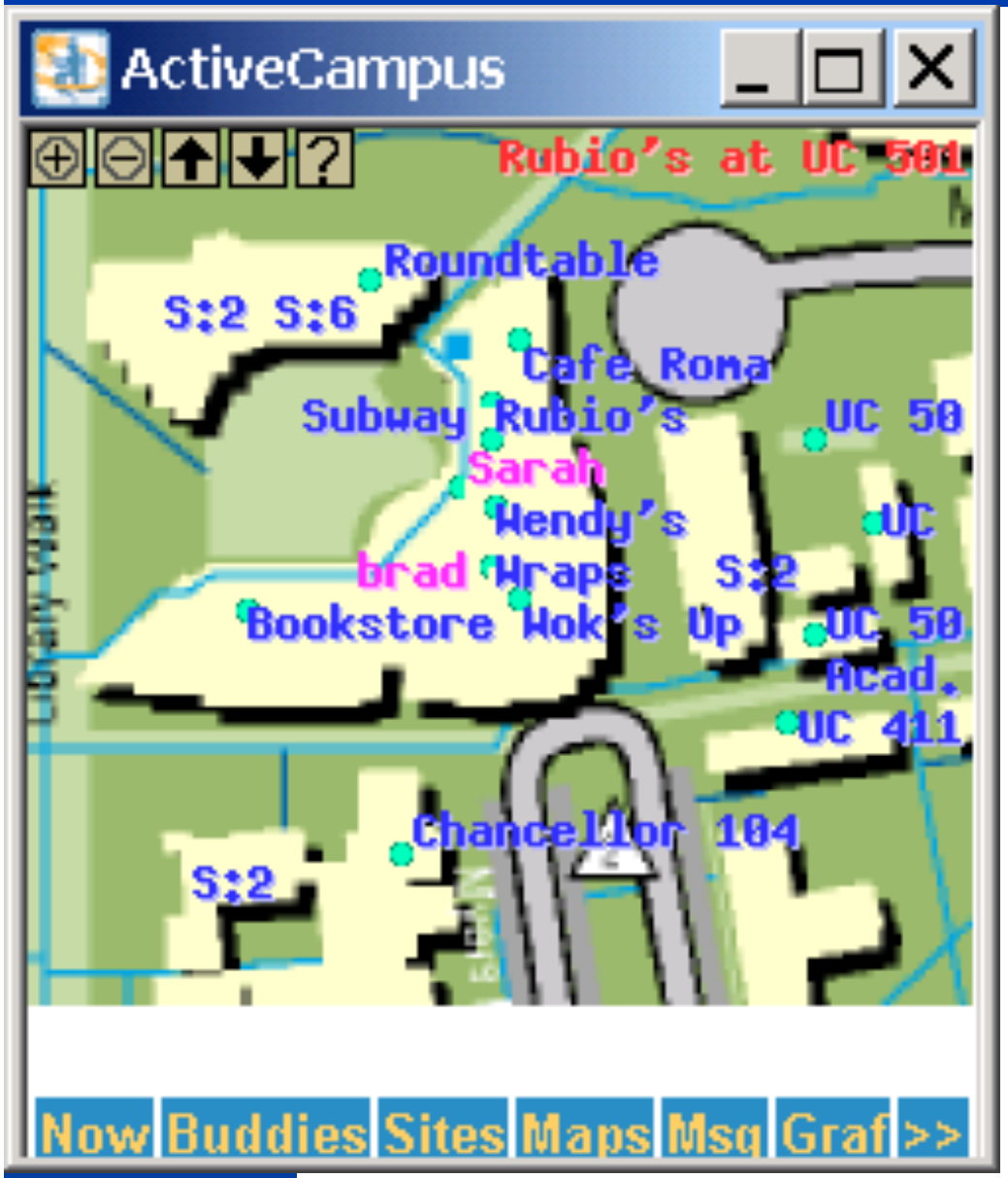
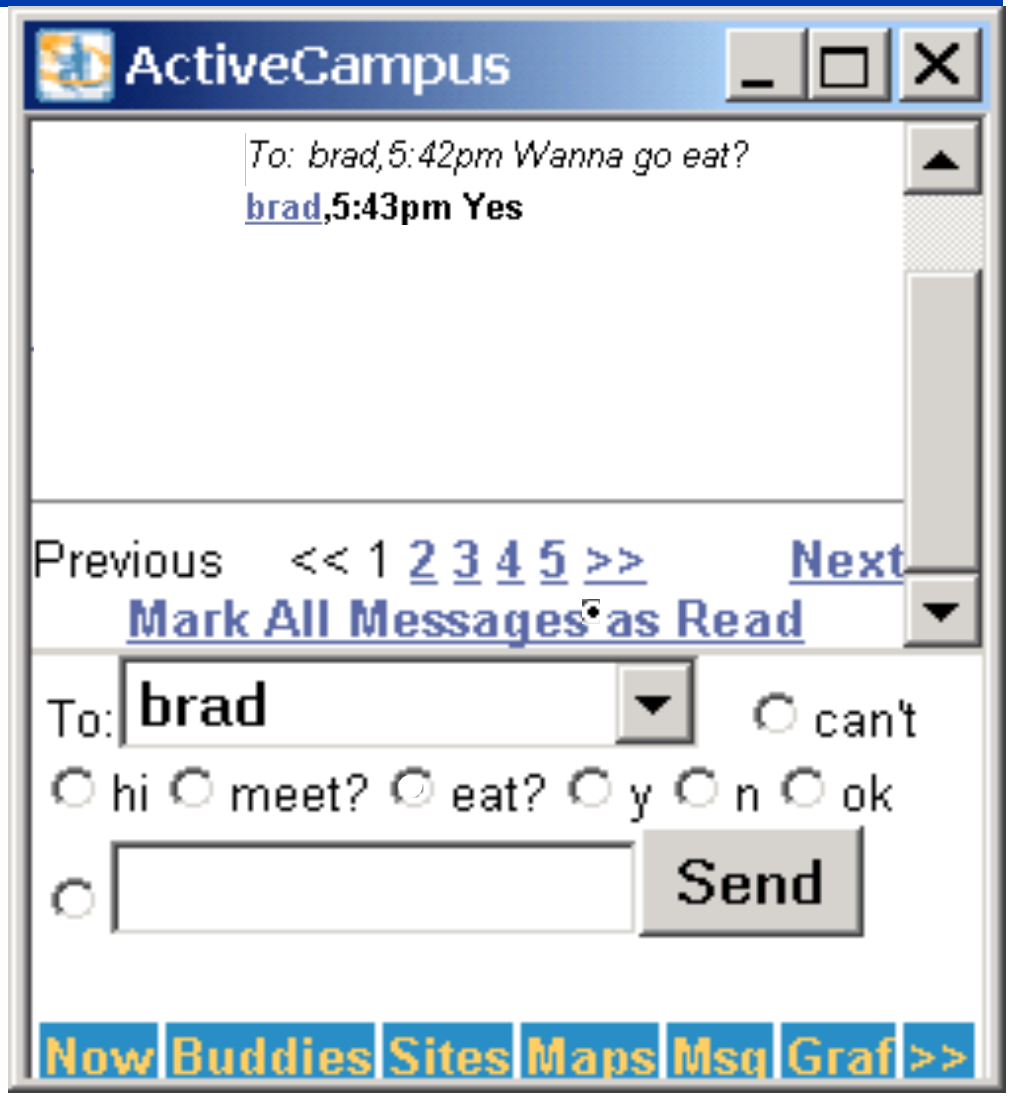
The Undergraduates are Explorers of the New World of Mobile Geolocation





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Source: Bill Griswold, CSE, UCSD

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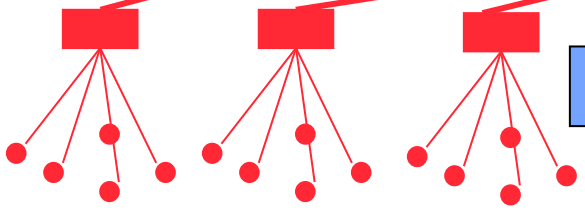
"Always-On" Internet
Enables Continuous Data Entry and Retrieval

Web Portal Customized to User Device

PDAs, Laptops, Phones
- **Real-Time Data Access**

SensorNets
- **Real-Time Data Entry**



Visualization and Display

Data Mining, Simulation, Modeling, Analysis, Data Fusion

Knowledge-Based Integration
Advanced Query Processing

Database Systems, Grid Storage, File Systems

High speed networking

Networked Storage (SAN)

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Source: UCSD/Cal(IT)^2

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NSF's ROADnet—Bringing SensorNets to the Dirt Roads and the High Seas

- **High Bandwidth Wireless Internet**
  - Linking Sensors for:
    - Seismology
    - Oceanography
    - Climate
    - Hydrology
    - Ecology
    - Geodesy
  - Real-Time Data Management
- **Joint Collaboration Between:**
  - SIO / IGPP
  - UCSD
  - SDSC / HPWREN
  - SDSU
  - Cal-(IT)^2 Industrial Cost Sharing

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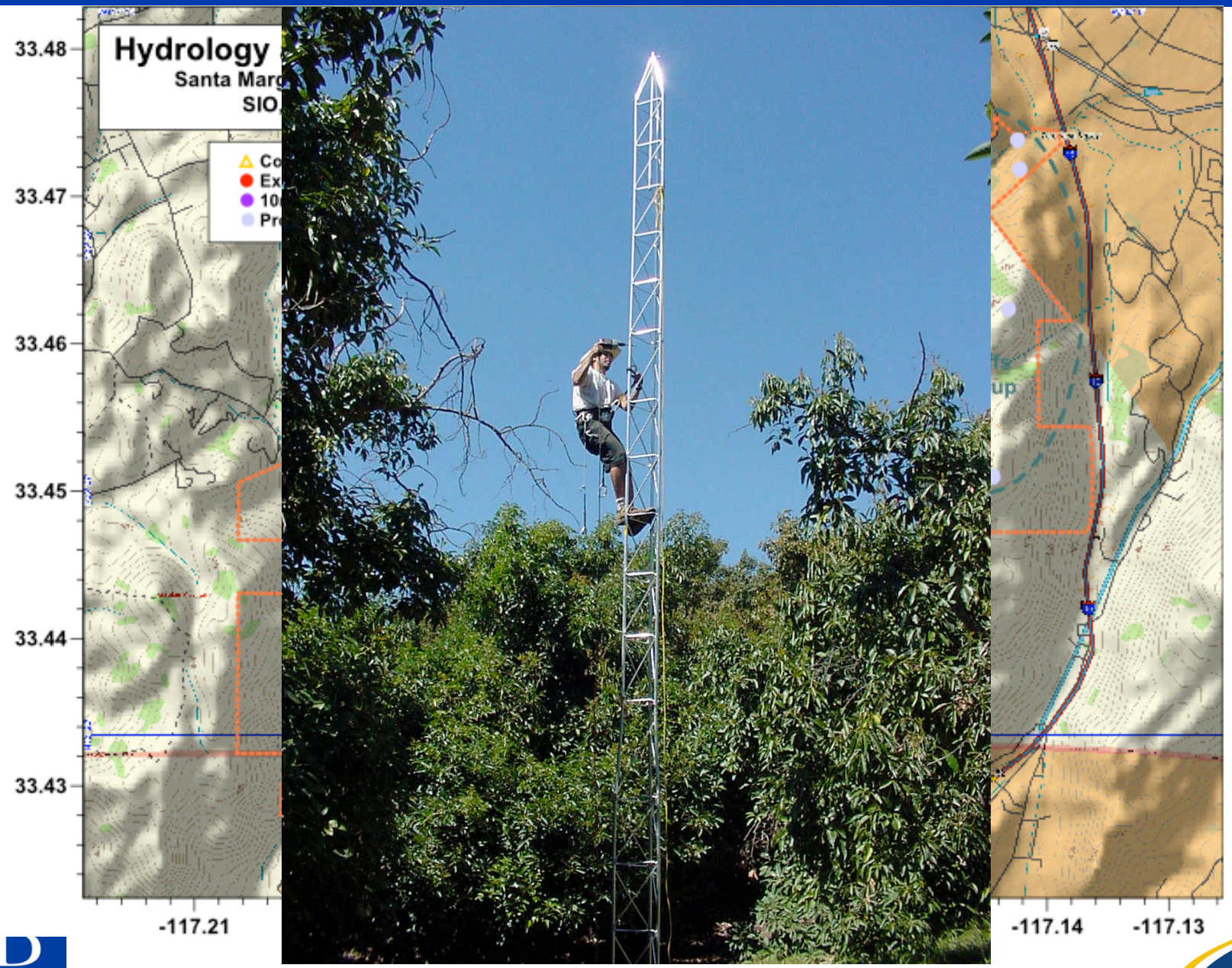
http://roadnet.ucsd.edu/

Environmental SensorNets--Water and Climate Instruments in the Santa Margarita Ecological Reserve



Source, Dan Cayan, UCSD SIO

Distributed Interactive Video Arrays
Coronado Bridge Demonstration May 15, 2002

- **UCSD Team Members**
  - ROADnet Team
  - SDSC, HPWREN
  - SIO, Seismic Sensors
  - Structural Engineering, Bridge Sensors
  - CVRR Lab, Video Arrays
- **ONR, SPAWAR**

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Source: Mohan Trivedi, UC San Diego

CVRR Computer Vision and Robotics Research Laboratory

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Multi-Media Control Room
UCSD Computer Vision and Robotics Research Lab

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http://hpwren.ucsd.edu/news/020524.html

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Cal-(IT)^2 Homeland Security Experiments During Super Bowl 2003

Vehicle detection software running on Seaport Village video feed

Super Bowl XXXVII sign from Seaport Village Command Center

Crane deploys cameras across from QUALCOMM Stadium

UCSD Triton sign on top of crane across from QUALCOMM Stadium

CVRR
Computer Vision and Robotics Research Laboratory

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UCSD Worked Closely with SD Police (Chief Maheu)

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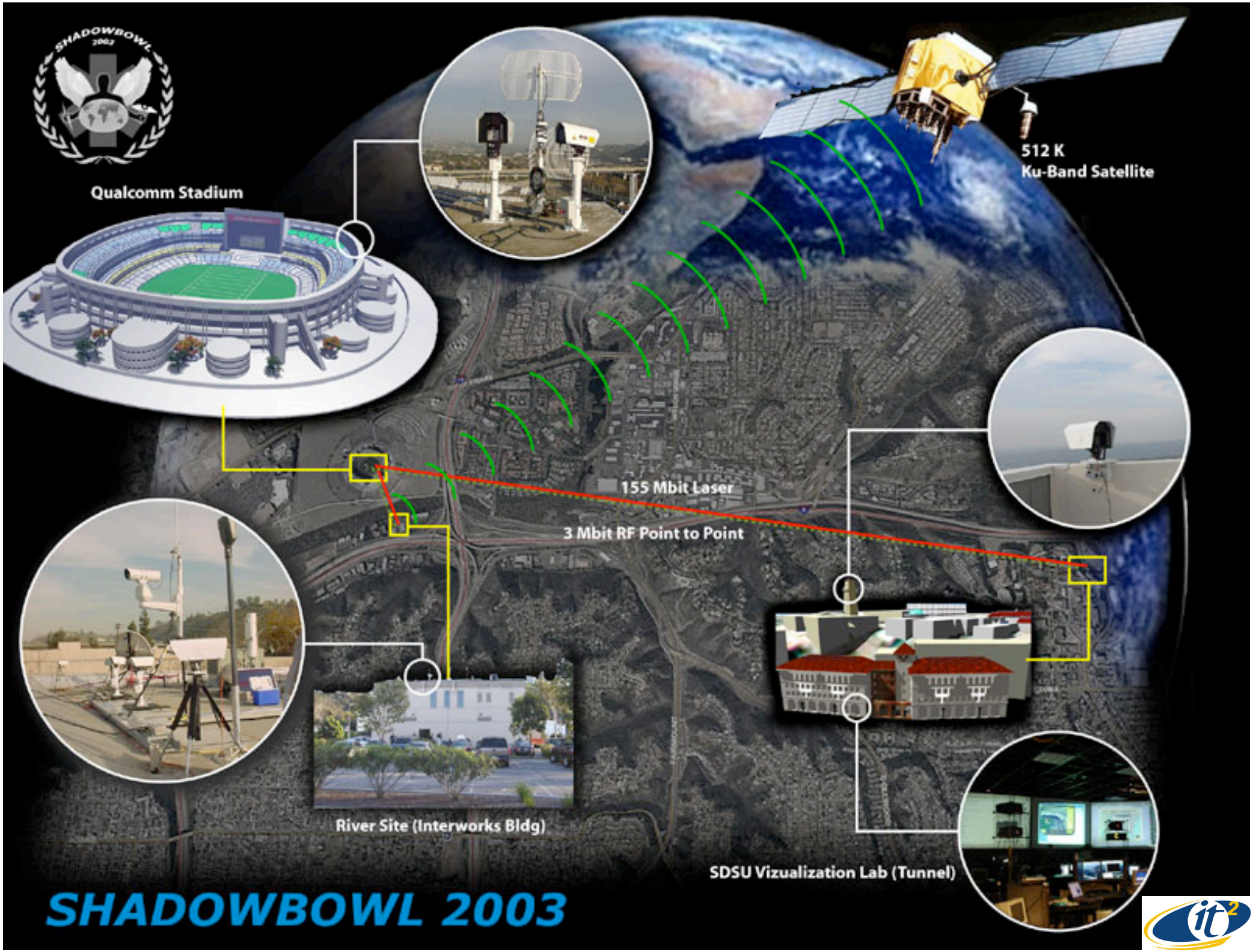
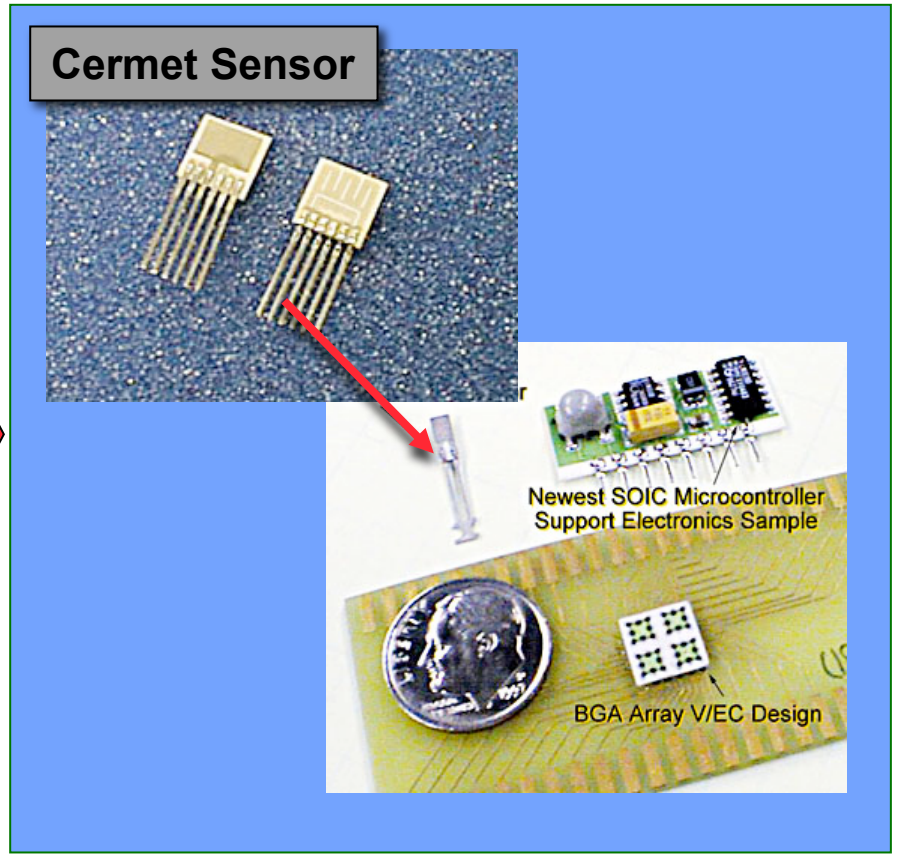

SHADOWBOWL 2003
Qualcomm Stadium
512 K
Ku-Band Satellite
155 Mbit Laser
3 Mbit RF Point to Point
River Site (Interworks Bldg)
SDSU Vizualization Lab (Tunnel)
SHADOWBOWL 2003

Goal for This Decade
Put Laboratories on a Chip



$ 300,000

$ 10

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Source: Greg McRae, MIT and ANL

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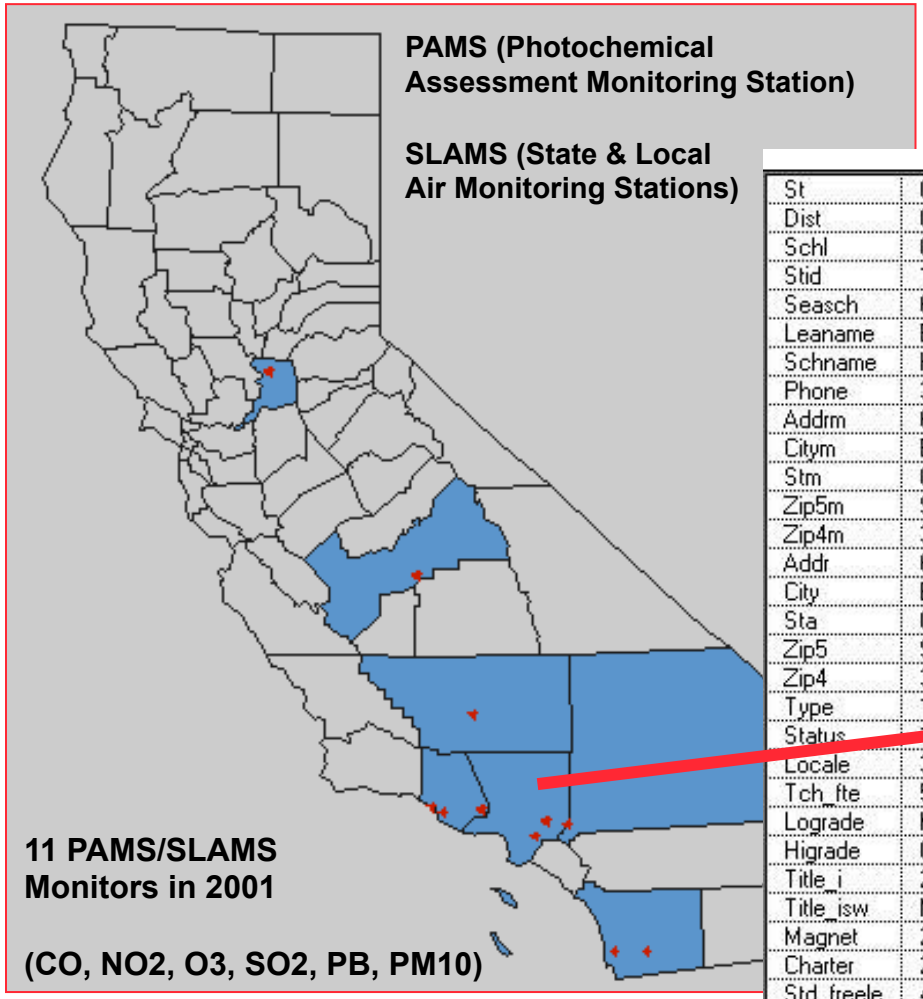
Can Schools Become a Source for Data Intensive Science?

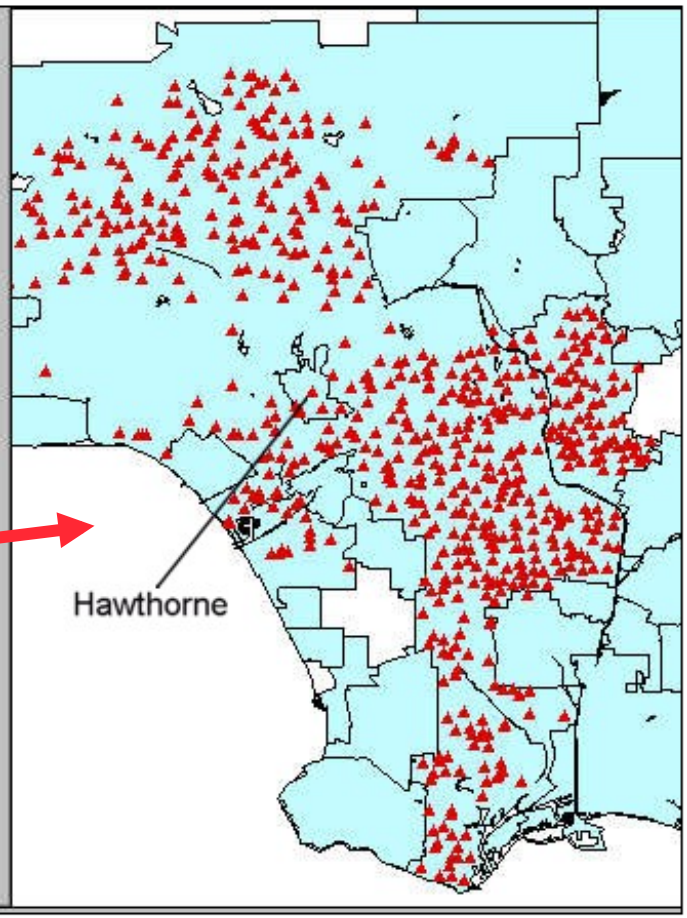
US EPA PAMS Sites



California Air Resources Board

Schools in Los Angeles Unified School District

St	06
Dist	04830
Schl	00474
Stid	1964311
Seasch	6011761
Leaname	BEVERLY HILLS UNIFIED
Schname	HAWTHORNE ELEMENT
Phone	3102766102
Addrm	624 N. REXFORD DR.
Citym	BEVERLY HILLS
Stm	CA
Zip5m	90210
Zip4m	3312
Addr	624 N. REXFORD DR.
City	BEVERLY HILLS
Sta	CA
Zip5	90210
Zip4	3312
Type	1
Status	
Locale	3
Tch_fte	59
Lograde	KG
Higrade	08
Title_i	2
Title_isw	N
Magnet	2
Charter	2
Std_freele	41
Std_redule	10



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Potential for Dramatic Increase in Coverage!

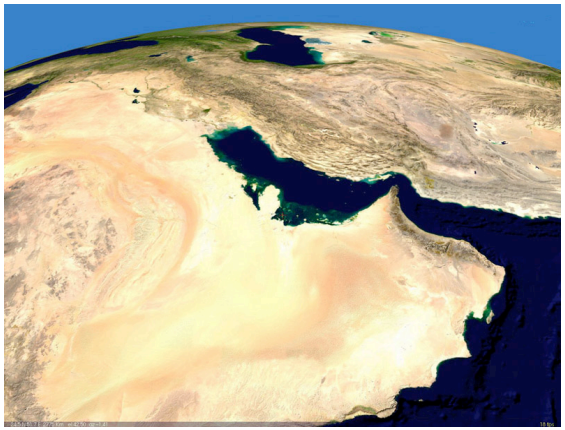
it²

How Can We Make Scientific Discovery as Engaging as Video Games?

Source:
Mike Bailey,
SDSC

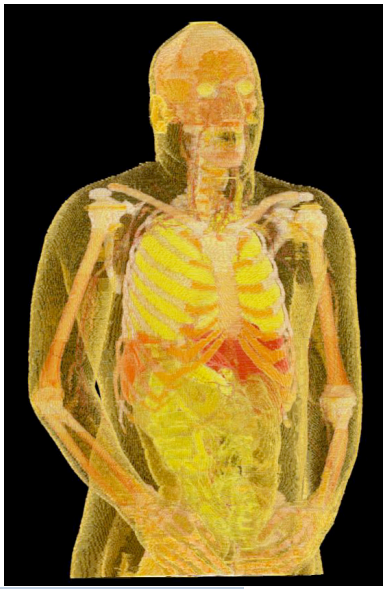
Interactive 3D APPLICATIONS:

Geography

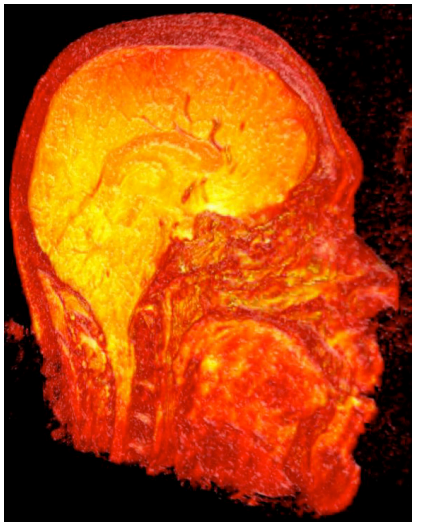


Underground Earth Sciences

Anatomy



Neurosciences



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The Preuss School UCSD

SDSC

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